Zezula_Mateusz_HW_13

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Creating relevant datasets/functions

```r
if (!exists("mtrain")) {
  mtrain <- read.csv("mnist_train.csv", header = F) %>% as.matrix
  classify <- mtrain[, 1]
  y <- factor(classify, levels = c(0, 1))

  for (i in 1:length(classify)) {
    number <- classify[i]
    if (number == 3){
      number <- 1
    } else {
      number <- 0
    }
    y[i] <- number
  }
  y <- factor(y, levels = c(0, 1))
  y <- y[1:1000]

  mtrain <- mtrain[,-1]/256
  colnames(mtrain) <- 1:(28^2)
  x <- mtrain[1:1000,]
}

if (!exists("mtest")) {
  mtest <- read.csv("mnist_train.csv", header = F) %>% as.matrix
  classify <- mtest[, 1]
  test.y <- factor(classify, levels = c(0, 1))

  for (i in 1:length(classify)) {
    number <- classify[i]
    if (number == 3){
      number <- 1
    } else {
      number <- 0
    }
    test.y[i] <- number
  }
  test.y <- factor(test.y, levels = c(0, 1))
  test.y <- test.y[1001:2000]

  mtest <- mtest[,-1]/256
  colnames(mtest) <- 1:(28^2)
  test.x <- mtest[1001:2000,]
}

prediction_error <- function(x, y, nnet.result) {
  true_y <- y
    pred_y <- predict(nnet.result, x)

  n_samples <- nrow(x)
  error <- sum(true_y != pred_y)/n_samples
  return (error)
}
```

Training with decay = 0

```
tuning_df.nd <- data.frame(size = 5:10, decay = 0)
fitControl.nd <- trainControl(method = "none")
fitControl.nd <- trainControl(method = "repeatedcv",
                              number = 2,
                              repeats = 3)


out.nd <- caret::train(x = x, y = y, method = "nnet",
                       trControl = fitControl.nd,
                       tuneGrid = tuning_df.nd,
                       maxit = 1000,
                       MaxNWts = 10000)
```

```
## # weights:  3931
## initial  value 216.381583
## iter  10 value 65.536456
## iter  20 value 52.751440
## iter  30 value 44.322915
## iter  40 value 40.023604
## iter  50 value 39.865573
## iter  60 value 39.505910
## iter  70 value 37.851108
## iter  80 value 35.357818
## iter  90 value 31.015763
## iter 100 value 31.001910
## iter 110 value 30.915693
## iter 120 value 30.902081
## iter 130 value 30.897637
## iter 140 value 30.888726
## iter 150 value 30.694242
## iter 160 value 26.788018
## iter 170 value 22.314946
## iter 180 value 13.148996
## iter 190 value 8.435469
## iter 200 value 3.145937
## iter 210 value 2.710180
## iter 220 value 2.707500
## iter 230 value 2.706463
## iter 240 value 2.705083
## iter 250 value 2.704809
## iter 260 value 2.704751
## iter 270 value 2.704169
## iter 280 value 2.703975
## iter 290 value 2.703644
## iter 300 value 2.703498
## iter 310 value 2.703463
## final  value 2.703457
## converged
## # weights:  4717
## initial  value 178.272265
## iter  10 value 60.122476
## iter  20 value 17.505058
## iter  30 value 12.325686
## iter  40 value 11.755370
## iter  50 value 10.981308
## iter  60 value 10.222789
## iter  70 value 10.093974
## iter  80 value 8.024602
## iter  90 value 8.024205
## final  value 8.024181
## converged
## # weights:  5503
## initial  value 207.711855
## iter  10 value 17.942178
## iter  20 value 1.642586
## iter  30 value 0.122741
## iter  40 value 0.017338
## iter  50 value 0.003369
## iter  60 value 0.000602
## iter  70 value 0.000310
## iter  80 value 0.000191
## final  value 0.000097
## converged
## # weights:  6289
## initial  value 393.641690
## iter  10 value 91.160508
## iter  20 value 35.808905
## iter  30 value 30.666059
## iter  40 value 23.120204
## iter  50 value 12.372636
## iter  60 value 10.316416
## iter  70 value 9.595105
## iter  80 value 9.577986
## iter  90 value 9.576311
## iter 100 value 9.575960
```

```
## iter 110 value 9.572818
## iter 120 value 2.989452
## iter 130 value 2.253479
## iter 140 value 2.250089
## iter 150 value 2.249619
## iter 160 value 2.249410
## iter 170 value 2.249385
## final   value 2.249344
## converged
## # weights:  7075
## initial  value 726.528111
## iter  10 value 117.603280
## iter  20 value 63.151738
## iter  30 value 48.408174
## iter  40 value 48.272259
## iter  50 value 48.265859
## iter  60 value 48.173311
## iter  70 value 25.708715
## iter  80 value 13.719095
## iter  90 value 12.335703
## iter 100 value 12.323015
## iter 110 value 10.400871
## iter 120 value 7.261888
## iter 130 value 6.864746
## iter 140 value 6.015072
## iter 150 value 5.363548
## iter 160 value 3.446334
## iter 170 value 2.202683
## iter 180 value 1.444193
## iter 190 value 0.017119
## iter 200 value 0.000153
## iter 200 value 0.000088
## iter 200 value 0.000078
## final   value 0.000078
## converged
## # weights:  7861
## initial  value 191.789315
## iter  10 value 33.516009
## iter  20 value 0.412928
## iter  30 value 0.026120
## iter  40 value 0.004456
## iter  50 value 0.000509
## iter  60 value 0.000309
## final   value 0.000056
## converged
## # weights:  3931
## initial  value 234.074170
## iter  10 value 15.664688
## iter  20 value 2.953432
## iter  30 value 1.914040
## iter  40 value 0.540379
## iter  50 value 0.011575
## iter  60 value 0.000277
## final   value 0.000078
## converged
## # weights:  4717
## initial  value 610.201868
## iter  10 value 71.457656
## iter  20 value 29.012826
## iter  30 value 6.689703
## iter  40 value 0.266582
## iter  50 value 0.001842
## iter  60 value 0.000595
## iter  70 value 0.000402
## iter  80 value 0.000202
## iter  90 value 0.000152
## final   value 0.000078
## converged
## # weights:  5503
## initial  value 297.444024
## iter  10 value 146.216761
## iter  20 value 43.626621
```

```
## iter  30 value 8.858349
## iter  40 value 4.950661
## iter  50 value 0.127233
## iter  60 value 0.033408
## iter  70 value 0.014212
## iter  80 value 0.005648
## iter  90 value 0.000867
## iter 100 value 0.000467
## iter 110 value 0.000119
## final   value 0.000092
## converged
## # weights:  6289
## initial   value 541.097822
## iter  10 value 8.758372
## iter  20 value 0.036973
## iter  30 value 0.000493
## final   value 0.000069
## converged
## # weights:  7075
## initial   value 169.994181
## iter  10 value 13.360878
## iter  20 value 0.106312
## iter  30 value 0.007014
## iter  40 value 0.000703
## iter  50 value 0.000173
## final   value 0.000083
## converged
## # weights:  7861
## initial   value 320.921380
## iter  10 value 124.296870
## iter  20 value 41.223848
## iter  30 value 36.696068
## iter  40 value 31.105029
## iter  50 value 16.521167
## iter  60 value 16.356087
## iter  70 value 13.944959
## iter  80 value 13.938485
## final   value 13.938466
## converged
## # weights:  3931
## initial   value 304.976873
## iter  10 value 38.919325
## iter  20 value 19.033809
## iter  30 value 6.982977
## iter  40 value 6.194225
## iter  50 value 6.182960
## iter  60 value 6.182665
## final   value 6.182656
## converged
## # weights:  4717
## initial   value 362.674997
## iter  10 value 155.037673
## iter  20 value 113.497640
## iter  30 value 79.843559
## iter  40 value 41.368990
## iter  50 value 19.750695
## iter  60 value 16.187286
## iter  70 value 16.181236
## iter  80 value 16.172766
## iter  90 value 15.733092
## iter 100 value 15.732426
## final   value 15.732389
## converged
## # weights:  5503
## initial   value 640.540657
## iter  10 value 53.365580
## iter  20 value 18.521973
## iter  30 value 11.985447
## iter  40 value 11.270420
## iter  50 value 10.422083
## iter  60 value 9.347242
## iter  70 value 0.464272
```

```
## iter  80 value 0.007048
## iter  90 value 0.000127
## iter  90 value 0.000070
## iter  90 value 0.000070
## final  value 0.000070
## converged
## # weights:  6289
## initial  value 410.280013
## iter  10 value 33.560739
## iter  20 value 10.962787
## iter  30 value 5.592201
## iter  40 value 0.157276
## iter  50 value 0.006914
## iter  60 value 0.003286
## iter  70 value 0.000815
## final  value 0.000093
## converged
## # weights:  7075
## initial  value 379.568947
## iter  10 value 155.840042
## iter  20 value 137.853587
## iter  30 value 53.888277
## iter  40 value 41.944800
## iter  50 value 31.882038
## iter  60 value 31.804113
## iter  70 value 29.186380
## iter  80 value 26.279135
## iter  90 value 26.275726
## iter 100 value 26.272895
## iter 110 value 22.852560
## iter 120 value 22.850908
## iter 130 value 22.850657
## final  value 22.850656
## converged
## # weights:  7861
## initial  value 200.577438
## iter  10 value 28.258312
## iter  20 value 9.064453
## iter  30 value 3.988527
## iter  40 value 0.120917
## iter  50 value 0.012013
## iter  60 value 0.002034
## iter  70 value 0.000698
## iter  80 value 0.000243
## iter  90 value 0.000206
## final  value 0.000079
## converged
## # weights:  3931
## initial  value 301.676129
## iter  10 value 109.007369
## iter  20 value 34.974511
## iter  30 value 26.410151
## iter  40 value 21.102712
## iter  50 value 17.687132
## iter  60 value 12.874122
## iter  70 value 12.853790
## iter  80 value 12.341547
## iter  90 value 2.682346
## iter 100 value 0.011547
## iter 110 value 0.000804
## iter 120 value 0.000533
## iter 130 value 0.000239
## final  value 0.000064
## converged
## # weights:  4717
## initial  value 351.425503
## iter  10 value 153.246427
## iter  20 value 107.082737
## iter  30 value 70.260946
## iter  40 value 67.128351
## iter  50 value 17.476168
## iter  60 value 13.277776
```

```
## iter  70 value 10.861937
## iter  80 value 8.940836
## iter  90 value 3.815288
## iter 100 value 3.810692
## iter 110 value 3.808783
## iter 120 value 3.804573
## iter 130 value 3.803587
## iter 140 value 3.803358
## iter 150 value 3.803295
## iter 160 value 3.803290
## iter 160 value 3.803290
## final  value 3.803288
## converged
## # weights:  5503
## initial  value 243.435452
## iter  10 value 59.776164
## iter  20 value 26.624481
## iter  30 value 24.010798
## iter  40 value 24.000516
## iter  50 value 23.998619
## iter  60 value 21.502423
## iter  70 value 21.072286
## iter  80 value 21.063855
## iter  90 value 21.063202
## iter 100 value 21.055340
## iter 110 value 21.044546
## iter 120 value 21.032902
## iter 130 value 20.752793
## iter 140 value 20.151088
## iter 150 value 19.405344
## iter 160 value 15.897539
## iter 170 value 12.197798
## iter 180 value 9.957244
## iter 190 value 3.029919
## iter 200 value 2.788357
## iter 210 value 2.772992
## iter 220 value 2.772835
## iter 230 value 2.772638
## iter 240 value 2.772612
## final  value 2.772590
## converged
## # weights:  6289
## initial  value 206.246954
## iter  10 value 28.472150
## iter  20 value 3.905598
## iter  30 value 0.072365
## iter  40 value 0.002881
## iter  50 value 0.000135
## final  value 0.000099
## converged
## # weights:  7075
## initial  value 742.113934
## iter  10 value 32.850068
## iter  20 value 9.468123
## iter  30 value 0.273739
## iter  40 value 0.002732
## final  value 0.000072
## converged
## # weights:  7861
## initial  value 430.028034
## iter  10 value 32.888221
## iter  20 value 13.934093
## iter  30 value 12.839581
## iter  40 value 7.226496
## iter  50 value 7.101861
## iter  60 value 7.086323
## iter  70 value 6.990975
## iter  80 value 6.805925
## iter  90 value 5.992942
## iter 100 value 0.253734
## iter 110 value 0.011777
## iter 120 value 0.001899
```

```
## iter 130 value 0.000399
## final  value 0.000054
## converged
## # weights:  3931
## initial  value 454.805572
## final  value 153.473729
## converged
## # weights:  4717
## initial  value 610.692455
## iter  10 value 64.805992
## iter  20 value 20.277501
## iter  30 value 1.189290
## iter  40 value 0.198271
## iter  50 value 0.017779
## iter  60 value 0.001801
## iter  70 value 0.000602
## iter  80 value 0.000155
## iter  80 value 0.000091
## iter  80 value 0.000090
## final  value 0.000090
## converged
## # weights:  5503
## initial  value 332.371916
## iter  10 value 83.467901
## iter  20 value 21.245433
## iter  30 value 14.535095
## iter  40 value 12.117278
## iter  50 value 7.798575
## iter  60 value 1.674386
## iter  70 value 0.104402
## iter  80 value 0.022642
## iter  90 value 0.001841
## iter 100 value 0.001420
## iter 110 value 0.000963
## iter 120 value 0.000465
## iter 130 value 0.000165
## iter 140 value 0.000165
## final  value 0.000165
## converged
## # weights:  6289
## initial  value 747.092329
## final  value 153.473805
## converged
## # weights:  7075
## initial  value 852.516672
## iter  10 value 9.965147
## iter  20 value 0.261047
## iter  30 value 0.014229
## iter  40 value 0.003447
## iter  50 value 0.000271
## iter  60 value 0.000113
## iter  60 value 0.000085
## iter  60 value 0.000084
## final  value 0.000084
## converged
## # weights:  7861
## initial  value 454.992280
## iter  10 value 145.216768
## iter  20 value 68.982245
## iter  30 value 51.219973
## iter  40 value 49.551831
## iter  50 value 33.004259
## iter  60 value 1.286614
## iter  70 value 0.011276
## iter  80 value 0.001646
## iter  90 value 0.000627
## final  value 0.000083
## converged
## # weights:  3931
## initial  value 283.758184
## iter  10 value 18.801357
## iter  20 value 2.329072
```

```
## iter  30 value 1.469337
## iter  40 value 0.090354
## iter  50 value 0.022117
## iter  60 value 0.002662
## iter  70 value 0.000494
## iter  80 value 0.000265
## iter  90 value 0.000250
## iter 100 value 0.000244
## final   value 0.000244
## converged
## # weights:  4717
## initial   value 508.901526
## iter  10 value 42.330197
## iter  20 value 21.260754
## iter  30 value 19.446139
## iter  40 value 16.837517
## iter  50 value 15.439409
## iter  60 value 12.595584
## iter  70 value 10.831905
## iter  80 value 10.591833
## iter  90 value 10.474166
## iter 100 value 9.402148
## iter 110 value 8.740930
## iter 120 value 7.874045
## iter 130 value 7.846952
## iter 140 value 6.756501
## iter 150 value 6.731182
## iter 160 value 6.730687
## iter 170 value 6.730659
## iter 180 value 6.730624
## iter 190 value 6.730609
## final   value 6.730582
## converged
## # weights:  5503
## initial   value 338.773313
## iter  10 value 93.894414
## iter  20 value 8.509411
## iter  30 value 6.234922
## iter  40 value 6.226386
## iter  50 value 5.916393
## iter  60 value 4.849959
## iter  70 value 4.844900
## iter  80 value 4.840849
## iter  90 value 4.839413
## iter 100 value 4.839269
## iter 110 value 4.797171
## iter 120 value 4.640559
## iter 130 value 4.069669
## iter 140 value 3.749419
## iter 150 value 0.031922
## iter 160 value 0.000172
## iter 170 value 0.000165
## final   value 0.000165
## converged
## # weights:  6289
## initial   value 451.206488
## iter  10 value 155.830975
## iter  20 value 139.268688
## iter  30 value 30.704105
## iter  40 value 18.273185
## iter  50 value 18.077672
## iter  60 value 18.068461
## iter  70 value 18.007010
## iter  80 value 8.331252
## iter  90 value 0.008118
## iter 100 value 0.004195
## iter 110 value 0.000552
## final   value 0.000095
## converged
## # weights:  7075
## initial   value 705.853596
## iter  10 value 64.490031
```

```
## iter  20 value 23.585557
## iter  30 value 22.911584
## iter  40 value 17.834679
## iter  50 value 17.490196
## iter  60 value 17.149625
## iter  70 value 17.136788
## iter  80 value 16.677273
## iter  90 value 16.396851
## iter 100 value 13.654733
## iter 110 value 12.857187
## iter 120 value 12.460065
## iter 130 value 10.192782
## iter 140 value 6.916512
## iter 150 value 0.445533
## iter 160 value 0.047550
## iter 170 value 0.007321
## iter 180 value 0.000915
## iter 190 value 0.000402
## final  value 0.000097
## converged
## # weights:  7861
## initial  value 378.533567
## iter  10 value 20.241736
## iter  20 value 10.740573
## iter  30 value 2.007536
## iter  40 value 0.130750
## iter  50 value 0.027761
## iter  60 value 0.010682
## iter  70 value 0.004297
## iter  80 value 0.001801
## iter  90 value 0.000564
## iter 100 value 0.000320
## iter 110 value 0.000156
## final  value 0.000094
## converged
## # weights:  7075
## initial  value 1245.150199
## iter  10 value 33.874239
## iter  20 value 1.470106
## iter  30 value 0.019318
## iter  40 value 0.000390
## iter  50 value 0.000153
## final  value 0.000087
## converged
```

```
pred_error <- prediction_error(x, y, out.nd)
cat("training dataset prediction error", pred_error, "\n")
```

```
## training dataset prediction error 0
```

```
pred_error <- prediction_error(test.x, test.y, out.nd)
cat("test dataset prediction error", pred_error, "\n")
```

```
## test dataset prediction error 0.055
```

```
out.nd
```

```
## Neural Network
##
## 1000 samples
##  784 predictor
##    2 classes: '0', '1'
##
## No pre-processing
## Resampling: Cross-Validated (2 fold, repeated 3 times)
## Summary of sample sizes: 501, 499, 500, 500, 499, 501, ...
## Resampling results across tuning parameters:
##
##   size  Accuracy   Kappa
##    5    0.9523559  0.6409008
##    6    0.9556785  0.7208855
##    7    0.9620019  0.7610124
##    8    0.9506885  0.6217403
##    9    0.9636732  0.7686732
##   10    0.9573412  0.7363953
##
## Tuning parameter 'decay' was held constant at a value of 0
## Accuracy was used to select the optimal model using the largest value.
## The final values used for the model were size = 9 and decay = 0.
```

Training with varying decay

```
tuning_df.d <- data.frame(size = 5:10, decay = c(1, 2, 3))
fitControl.d <- trainControl(method = "none")
fitControl.d <- trainControl(method = "repeatedcv",
                             number = 2,
                             repeats = 3)

out.d <- caret::train(x = x, y = y, method = "nnet",
                      trControl = fitControl.d,
                      tuneGrid = tuning_df.d,
                      maxit = 1000,
                      MaxNWts = 10000)
```

```
## # weights:  3931
## initial  value 940.298040
## iter  10 value 129.133648
## iter  20 value 83.542182
## iter  30 value 61.772710
## iter  40 value 56.535474
## iter  50 value 53.729911
## iter  60 value 50.474610
## iter  70 value 49.946456
## iter  80 value 49.881516
## iter  90 value 49.881203
## iter  90 value 49.881202
## iter  90 value 49.881202
## final  value 49.881202
## converged
## # weights:  4717
## initial  value 1988.256088
## iter  10 value 223.830328
## iter  20 value 103.413366
## iter  30 value 88.240076
## iter  40 value 79.845905
## iter  50 value 77.336698
## iter  60 value 74.756617
## iter  70 value 74.076192
## iter  80 value 73.905929
## iter  90 value 73.812641
## iter 100 value 73.807103
## final  value 73.807028
## converged
## # weights:  5503
## initial  value 2959.751360
## iter  10 value 210.162703
## iter  20 value 104.638731
## iter  30 value 96.479545
## iter  40 value 93.472848
## iter  50 value 90.818776
## iter  60 value 90.090560
## iter  70 value 89.928575
## iter  80 value 89.888600
## iter  90 value 89.868248
## iter 100 value 89.867730
## iter 110 value 89.867631
## final  value 89.867630
## converged
## # weights:  6289
## initial  value 1296.003556
## iter  10 value 158.489458
## iter  20 value 77.509697
## iter  30 value 58.478023
## iter  40 value 54.534387
## iter  50 value 51.292205
## iter  60 value 49.016986
## iter  70 value 48.549893
## iter  80 value 48.386411
## iter  90 value 48.352428
## iter 100 value 48.344328
## iter 110 value 48.341663
## iter 120 value 48.341383
## iter 130 value 48.341360
## final  value 48.341359
## converged
## # weights:  7075
## initial  value 3243.594081
## iter  10 value 311.218474
## iter  20 value 157.762088
## iter  30 value 107.987261
## iter  40 value 93.486659
## iter  50 value 79.559017
## iter  60 value 75.526114
## iter  70 value 74.204907
## iter  80 value 73.730232
## iter  90 value 72.624621
```

```
## iter 100 value 72.372114
## iter 110 value 72.274213
## iter 120 value 72.203967
## iter 130 value 72.201556
## iter 140 value 72.201342
## iter 150 value 72.200995
## final   value 72.200979
## converged
## # weights:  7861
## initial  value 4313.023931
## iter  10 value 393.806391
## iter  20 value 145.793567
## iter  30 value 103.421698
## iter  40 value 92.966611
## iter  50 value 89.650896
## iter  60 value 88.629497
## iter  70 value 88.408271
## iter  80 value 88.278883
## iter  90 value 88.181714
## iter 100 value 88.159592
## iter 110 value 88.149738
## iter 120 value 88.147960
## iter 130 value 88.145593
## iter 140 value 88.145209
## final   value 88.145174
## converged
## # weights:  3931
## initial  value 1202.178496
## iter  10 value 108.892262
## iter  20 value 75.244416
## iter  30 value 64.913098
## iter  40 value 58.889602
## iter  50 value 50.860200
## iter  60 value 48.839145
## iter  70 value 48.259322
## iter  80 value 48.085243
## iter  90 value 48.077476
## iter 100 value 48.077104
## iter 110 value 48.077070
## iter 110 value 48.077070
## iter 110 value 48.077070
## final   value 48.077070
## converged
## # weights:  4717
## initial  value 1976.504537
## iter  10 value 163.267173
## iter  20 value 82.768980
## iter  30 value 72.706187
## iter  40 value 71.001610
## iter  50 value 70.886184
## iter  60 value 70.876307
## iter  70 value 70.869571
## final   value 70.869419
## converged
## # weights:  5503
## initial  value 2954.219509
## iter  10 value 248.258802
## iter  20 value 123.084103
## iter  30 value 98.830200
## iter  40 value 90.502600
## iter  50 value 86.393307
## iter  60 value 85.774236
## iter  70 value 85.645180
## iter  80 value 85.530833
## iter  90 value 85.527490
## final   value 85.527464
## converged
## # weights:  6289
## initial  value 1364.147638
## iter  10 value 190.817223
## iter  20 value 75.608983
## iter  30 value 63.013148
```

```
## iter  40 value 50.617283
## iter  50 value 46.944625
## iter  60 value 45.803026
## iter  70 value 45.671785
## iter  80 value 45.646155
## iter  90 value 45.645700
## final   value 45.645697
## converged
## # weights:  7075
## initial  value 2579.244269
## iter  10 value 330.587293
## iter  20 value 144.977362
## iter  30 value 84.232829
## iter  40 value 72.628518
## iter  50 value 69.976916
## iter  60 value 68.512963
## iter  70 value 68.303984
## iter  80 value 68.248627
## iter  90 value 68.230695
## iter 100 value 68.200041
## iter 110 value 68.192029
## iter 120 value 68.183371
## iter 130 value 68.178757
## iter 140 value 68.178613
## iter 150 value 68.178501
## final   value 68.178492
## converged
## # weights:  7861
## initial  value 4164.478452
## iter  10 value 561.847000
## iter  20 value 161.358590
## iter  30 value 117.548098
## iter  40 value 99.049890
## iter  50 value 89.692640
## iter  60 value 85.967377
## iter  70 value 84.507337
## iter  80 value 84.248250
## iter  90 value 84.103402
## iter 100 value 83.760831
## iter 110 value 83.541776
## iter 120 value 83.459516
## iter 130 value 83.437131
## iter 140 value 83.436007
## iter 150 value 83.433156
## iter 160 value 83.432799
## final   value 83.432789
## converged
## # weights:  3931
## initial  value 1261.384210
## iter  10 value 164.904656
## iter  20 value 69.722156
## iter  30 value 50.213461
## iter  40 value 47.287160
## iter  50 value 46.810696
## iter  60 value 46.775150
## iter  70 value 46.752782
## iter  80 value 46.742056
## iter  90 value 46.741895
## final   value 46.741894
## converged
## # weights:  4717
## initial  value 2155.137477
## iter  10 value 179.086897
## iter  20 value 101.899492
## iter  30 value 83.860432
## iter  40 value 75.330193
## iter  50 value 71.777380
## iter  60 value 70.927124
## iter  70 value 70.847076
## iter  80 value 70.843142
## iter  90 value 70.842383
## final   value 70.842352
```

```
## converged
## # weights:  5503
## initial  value 2969.132613
## iter  10 value 310.929355
## iter  20 value 118.924720
## iter  30 value 92.644350
## iter  40 value 88.646820
## iter  50 value 87.179930
## iter  60 value 86.898215
## iter  70 value 86.613814
## iter  80 value 86.435222
## iter  90 value 86.313220
## iter 100 value 86.305649
## iter 110 value 86.305415
## final  value 86.305396
## converged
## # weights:  6289
## initial  value 1531.590992
## iter  10 value 260.808894
## iter  20 value 129.106104
## iter  30 value 81.143024
## iter  40 value 67.588646
## iter  50 value 57.440944
## iter  60 value 51.849609
## iter  70 value 47.717880
## iter  80 value 46.833039
## iter  90 value 46.707615
## iter 100 value 46.670265
## iter 110 value 46.657396
## iter 120 value 46.599325
## iter 130 value 46.546611
## iter 140 value 46.540481
## iter 150 value 46.539794
## iter 160 value 46.539586
## iter 170 value 46.539331
## iter 180 value 46.539233
## final  value 46.539229
## converged
## # weights:  7075
## initial  value 2462.485354
## iter  10 value 175.342129
## iter  20 value 93.814851
## iter  30 value 74.644260
## iter  40 value 69.707307
## iter  50 value 68.771868
## iter  60 value 68.344558
## iter  70 value 67.868547
## iter  80 value 67.620437
## iter  90 value 67.600018
## iter 100 value 67.596311
## iter 110 value 67.595959
## final  value 67.595919
## converged
## # weights:  7861
## initial  value 4367.799412
## iter  10 value 365.795135
## iter  20 value 176.517379
## iter  30 value 130.744237
## iter  40 value 103.819256
## iter  50 value 88.985546
## iter  60 value 85.320526
## iter  70 value 84.326077
## iter  80 value 84.104894
## iter  90 value 84.008303
## iter 100 value 83.983308
## iter 110 value 83.981142
## iter 120 value 83.980966
## final  value 83.980964
## converged
## # weights:  3931
## initial  value 1014.847954
## iter  10 value 152.790566
```

```
## iter  20 value 65.090143
## iter  30 value 56.585333
## iter  40 value 52.957481
## iter  50 value 50.293914
## iter  60 value 50.133407
## iter  70 value 50.126877
## iter  80 value 50.125879
## iter  90 value 50.125786
## final  value 50.125785
## converged
## # weights:  4717
## initial  value 1858.952683
## iter  10 value 186.969042
## iter  20 value 90.396705
## iter  30 value 79.503352
## iter  40 value 76.554278
## iter  50 value 74.547823
## iter  60 value 74.259302
## iter  70 value 74.184761
## iter  80 value 74.181394
## final  value 74.181361
## converged
## # weights:  5503
## initial  value 3148.966481
## iter  10 value 243.677932
## iter  20 value 118.645409
## iter  30 value 100.242744
## iter  40 value 94.161794
## iter  50 value 91.959359
## iter  60 value 90.739934
## iter  70 value 89.647849
## iter  80 value 89.426731
## iter  90 value 89.381029
## iter 100 value 89.372015
## iter 110 value 89.370179
## iter 120 value 89.369934
## iter 120 value 89.369933
## iter 120 value 89.369933
## final  value 89.369933
## converged
## # weights:  6289
## initial  value 1525.863925
## iter  10 value 387.729483
## iter  20 value 103.412108
## iter  30 value 66.178102
## iter  40 value 54.969602
## iter  50 value 51.885080
## iter  60 value 50.276426
## iter  70 value 48.393358
## iter  80 value 48.073426
## iter  90 value 47.971555
## iter 100 value 47.897542
## iter 110 value 47.826102
## iter 120 value 47.799178
## iter 130 value 47.792167
## iter 140 value 47.791861
## final  value 47.791851
## converged
## # weights:  7075
## initial  value 2672.561387
## iter  10 value 535.770174
## iter  20 value 134.645890
## iter  30 value 101.924168
## iter  40 value 83.542520
## iter  50 value 75.828033
## iter  60 value 73.404272
## iter  70 value 72.659872
## iter  80 value 72.294024
## iter  90 value 71.963997
## iter 100 value 71.413316
## iter 110 value 71.228832
## iter 120 value 71.162841
```

```
## iter 130 value 71.134037
## iter 140 value 71.129461
## iter 150 value 71.125472
## iter 160 value 71.121226
## iter 170 value 71.120601
## iter 180 value 71.120396
## final   value 71.120375
## converged
## # weights:  7861
## initial  value 4000.436985
## iter  10 value 297.566601
## iter  20 value 149.665539
## iter  30 value 103.342339
## iter  40 value 93.175031
## iter  50 value 89.762899
## iter  60 value 88.719744
## iter  70 value 88.595597
## iter  80 value 88.383785
## iter  90 value 87.841641
## iter 100 value 87.756028
## iter 110 value 87.703080
## iter 120 value 87.665804
## iter 130 value 87.661919
## final   value 87.661796
## converged
## # weights:  3931
## initial  value 966.056703
## iter  10 value 171.078320
## iter  20 value 98.519629
## iter  30 value 77.270822
## iter  40 value 64.481568
## iter  50 value 56.267903
## iter  60 value 54.631574
## iter  70 value 53.499107
## iter  80 value 53.056795
## iter  90 value 52.588932
## iter 100 value 52.118021
## iter 110 value 51.560560
## iter 120 value 51.357841
## iter 130 value 51.284189
## iter 140 value 51.275884
## iter 150 value 51.275663
## final   value 51.275661
## converged
## # weights:  4717
## initial  value 2028.121703
## iter  10 value 163.669590
## iter  20 value 115.815879
## iter  30 value 91.710208
## iter  40 value 86.676100
## iter  50 value 81.398315
## iter  60 value 77.812124
## iter  70 value 77.261700
## iter  80 value 77.226041
## iter  90 value 77.221867
## iter 100 value 77.221655
## final   value 77.221648
## converged
## # weights:  5503
## initial  value 3383.393686
## iter  10 value 404.795465
## iter  20 value 158.504019
## iter  30 value 120.383656
## iter  40 value 103.198011
## iter  50 value 96.226169
## iter  60 value 93.791857
## iter  70 value 93.484896
## iter  80 value 93.439431
## iter  90 value 93.429177
## iter 100 value 93.426182
## iter 110 value 93.425387
## final   value 93.425376
```

```
## converged
## # weights:  6289
## initial  value 1433.325499
## iter  10 value 179.772150
## iter  20 value 78.123978
## iter  30 value 64.941645
## iter  40 value 58.847674
## iter  50 value 52.930644
## iter  60 value 50.901372
## iter  70 value 50.417387
## iter  80 value 50.022609
## iter  90 value 49.582381
## iter 100 value 49.418669
## iter 110 value 49.395508
## iter 120 value 49.393349
## iter 130 value 49.393088
## iter 140 value 49.392693
## final  value 49.392654
## converged
## # weights:  7075
## initial  value 2726.187343
## iter  10 value 163.443568
## iter  20 value 99.347358
## iter  30 value 84.130695
## iter  40 value 79.716242
## iter  50 value 76.473743
## iter  60 value 75.514007
## iter  70 value 75.255757
## iter  80 value 75.039938
## iter  90 value 74.476477
## iter 100 value 74.258149
## iter 110 value 74.243259
## iter 120 value 74.242846
## final  value 74.242836
## converged
## # weights:  7861
## initial  value 4193.032759
## iter  10 value 385.179968
## iter  20 value 133.759279
## iter  30 value 102.990684
## iter  40 value 94.731889
## iter  50 value 92.242640
## iter  60 value 91.395126
## iter  70 value 91.270234
## iter  80 value 91.259444
## iter  90 value 91.253725
## iter 100 value 91.253274
## iter 110 value 91.252934
## iter 120 value 91.252725
## iter 130 value 91.252684
## final  value 91.252671
## converged
## # weights:  3931
## initial  value 910.918899
## iter  10 value 102.300034
## iter  20 value 57.706232
## iter  30 value 49.193240
## iter  40 value 46.301529
## iter  50 value 45.352003
## iter  60 value 44.886548
## iter  70 value 44.852382
## iter  80 value 44.845883
## iter  90 value 44.845545
## final  value 44.845540
## converged
## # weights:  4717
## initial  value 1833.112792
## iter  10 value 127.648210
## iter  20 value 84.986376
## iter  30 value 71.521200
## iter  40 value 68.599203
## iter  50 value 68.165511
```

```
## iter  60 value 68.145947
## iter  70 value 68.144341
## iter  80 value 68.144275
## final   value 68.144265
## converged
## # weights:  5503
## initial  value 2980.500857
## iter  10 value 505.391498
## iter  20 value 156.193773
## iter  30 value 95.010427
## iter  40 value 88.656526
## iter  50 value 86.236505
## iter  60 value 84.384145
## iter  70 value 83.627467
## iter  80 value 83.389493
## iter  90 value 83.313741
## iter 100 value 83.255072
## iter 110 value 83.251976
## iter 120 value 83.251769
## iter 130 value 83.251695
## final   value 83.251672
## converged
## # weights:  6289
## initial  value 1219.667904
## iter  10 value 105.492526
## iter  20 value 65.578628
## iter  30 value 51.088898
## iter  40 value 44.660270
## iter  50 value 43.200265
## iter  60 value 42.915334
## iter  70 value 42.885677
## iter  80 value 42.881697
## iter  90 value 42.881219
## iter 100 value 42.881108
## iter 110 value 42.881068
## final   value 42.881066
## converged
## # weights:  7075
## initial  value 2934.890443
## iter  10 value 305.563241
## iter  20 value 143.565629
## iter  30 value 110.848648
## iter  40 value 85.101113
## iter  50 value 71.890717
## iter  60 value 67.252727
## iter  70 value 65.920562
## iter  80 value 65.588151
## iter  90 value 65.353909
## iter 100 value 65.119577
## iter 110 value 65.099885
## iter 120 value 65.060303
## iter 130 value 65.031583
## iter 140 value 65.030871
## final   value 65.030870
## converged
## # weights:  7861
## initial  value 4341.025205
## iter  10 value 643.547447
## iter  20 value 230.479475
## iter  30 value 123.081556
## iter  40 value 98.027940
## iter  50 value 86.329344
## iter  60 value 82.659349
## iter  70 value 81.264770
## iter  80 value 80.508752
## iter  90 value 80.397286
## iter 100 value 80.362335
## iter 110 value 80.313219
## iter 120 value 80.298709
## iter 130 value 80.297491
## iter 140 value 80.297299
## final   value 80.297263
```

```
## converged
## # weights:  4717
## initial  value 2514.852112
## iter  10 value 403.227985
## iter  20 value 132.098478
## iter  30 value 120.274119
## iter  40 value 118.391573
## iter  50 value 115.935840
## iter  60 value 110.708675
## iter  70 value 109.619650
## iter  80 value 109.094097
## iter  90 value 108.845661
## iter 100 value 108.685870
## iter 110 value 108.665285
## iter 120 value 108.623667
## iter 130 value 108.571195
## iter 140 value 108.497451
## iter 150 value 107.502155
## iter 160 value 107.176370
## iter 170 value 107.173557
## final  value 107.173549
## converged
```

```
pred_error <- prediction_error(x, y, out.nd)
cat("training dataset prediction error", pred_error, "\n")
```

```
## training dataset prediction error 0
```

```
pred_error <- prediction_error(test.x, test.y, out.nd)
cat("test dataset prediction error", pred_error, "\n")
```

```
## test dataset prediction error 0.055
```

```
out.d
```

```
## Neural Network
##
## 1000 samples
##  784 predictor
##    2 classes: '0', '1'
##
## No pre-processing
## Resampling: Cross-Validated (2 fold, repeated 3 times)
## Summary of sample sizes: 501, 499, 500, 500, 501, 499, ...
## Resampling results across tuning parameters:
##
##   size  decay  Accuracy   Kappa
##    5    1      0.9710073  0.8104897
##    6    2      0.9713399  0.8075207
##    7    3      0.9670052  0.7725439
##    8    1      0.9710073  0.8104897
##    9    2      0.9710059  0.8050430
##   10    3      0.9670059  0.7715042
##
## Accuracy was used to select the optimal model using the largest value.
## The final values used for the model were size = 6 and decay = 2.
```