Customer Purchase Behavior

2024-07-22

```r
library(caret)
```

```
## Warning: package 'caret' was built under R version 4.4.1

## Loading required package: ggplot2

## Warning: package 'ggplot2' was built under R version 4.4.1

## Loading required package: lattice
```

```r
library(randomForest)
```

```
## Warning: package 'randomForest' was built under R version 4.4.1

## randomForest 4.7-1.1

## Type rfNews() to see new features/changes/bug fixes.

##
## Attaching package: 'randomForest'

## The following object is masked from 'package:ggplot2':
##
##     margin
```

```r
library(tidyverse)
```

```
## Warning: package 'tidyverse' was built under R version 4.4.1

## Warning: package 'tibble' was built under R version 4.4.1

## Warning: package 'tidyr' was built under R version 4.4.1

## Warning: package 'readr' was built under R version 4.4.1

## Warning: package 'purrr' was built under R version 4.4.1

## Warning: package 'dplyr' was built under R version 4.4.1

## Warning: package 'stringr' was built under R version 4.4.1

## Warning: package 'forcats' was built under R version 4.4.1

## Warning: package 'lubridate' was built under R version 4.4.1

## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.1
## v lubridate 1.9.3     v tibble    3.2.1
## v purrr     1.0.2     v tidyr     1.3.1

## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::combine()       masks randomForest::combine()
## x dplyr::filter()        masks stats::filter()
## x dplyr::lag()           masks stats::lag()
```

```
## x purrr::lift()          masks caret::lift()
## x randomForest::margin() masks ggplot2::margin()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```r
library(tree)
```

```
## Warning: package 'tree' was built under R version 4.4.1
```

```r
library(gbm)
```

```
## Warning: package 'gbm' was built under R version 4.4.1
```

```
## Loaded gbm 2.2.2
## This version of gbm is no longer under development. Consider transitioning to gbm3, https://github.co
```

```r
library(rpart)
library(rpart.plot)
```

```
## Warning: package 'rpart.plot' was built under R version 4.4.1
```

```r
library(ggplot2)
library(MLmetrics)
```

```
## Warning: package 'MLmetrics' was built under R version 4.4.1
```

```
##
## Attaching package: 'MLmetrics'
##
## The following objects are masked from 'package:caret':
##
##     MAE, RMSE
##
## The following object is masked from 'package:base':
##
##     Recall
```

```r
library(MLeval)
```

```
## Warning: package 'MLeval' was built under R version 4.4.1
```

```r
customers <- read.csv("C:/Users/argon/Documents/Desktop Prime/MS Business Analytics/Summer Semester/STA
colnames(customers)
```

```
## [1] "Age"                "Gender"             "AnnualIncome"
## [4] "NumberOfPurchases"  "ProductCategory"    "TimeSpentOnWebsite"
## [7] "LoyaltyProgram"     "DiscountsAvailed"   "PurchaseStatus"
```

```r
glimpse(customers)
```

```
## Rows: 1,500
## Columns: 9
## $ Age                <int> 40, 20, 27, 24, 31, 66, 39, 64, 43, 20, 66, 70, 54,~
## $ Gender             <int> 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1, 1, 1, ~
## $ AnnualIncome       <dbl> 66120.27, 23579.77, 127821.31, 137798.62, 99300.96,~
## $ NumberOfPurchases  <int> 8, 4, 11, 19, 19, 14, 16, 13, 20, 16, 11, 11, 9, 17~
## $ ProductCategory    <int> 0, 2, 2, 3, 1, 4, 3, 2, 1, 0, 1, 2, 2, 0, 1, 4, 4, ~
## $ TimeSpentOnWebsite <dbl> 30.568601, 38.240097, 31.633212, 46.167059, 19.8235~
## $ LoyaltyProgram     <int> 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 1, 0, 1, 1, 1, 0, 0, ~
## $ DiscountsAvailed   <int> 5, 5, 0, 4, 0, 2, 4, 0, 3, 5, 5, 4, 5, 1, 4, 0, 0, ~
## $ PurchaseStatus     <int> 1, 0, 1, 1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 0, 1, 0, 1, ~
```

```r
unique_customers <- customers %>%
  distinct()
glimpse(unique_customers)
```

```
## Rows: 1,388
## Columns: 9
## $ Age               <int> 40, 20, 27, 24, 31, 66, 39, 64, 43, 20, 66, 70, 54,~
## $ Gender            <int> 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1, 1, 1, ~
## $ AnnualIncome      <dbl> 66120.27, 23579.77, 127821.31, 137798.62, 99300.96,~
## $ NumberOfPurchases <int> 8, 4, 11, 19, 19, 14, 16, 13, 20, 16, 11, 11, 9, 17~
## $ ProductCategory   <int> 0, 2, 2, 3, 1, 4, 3, 2, 1, 0, 1, 2, 2, 0, 1, 4, 4, ~
## $ TimeSpentOnWebsite <dbl> 30.568601, 38.240097, 31.633212, 46.167059, 19.8235~
## $ LoyaltyProgram    <int> 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 1, 0, 1, 1, 1, 0, 0, ~
## $ DiscountsAvailed  <int> 5, 5, 0, 4, 0, 2, 4, 0, 3, 5, 5, 4, 5, 1, 4, 0, 0, ~
## $ PurchaseStatus    <int> 1, 0, 1, 1, 1, 0, 1, 0, 0, 1, 1, 1, 1, 0, 1, 0, 1, ~
```

```r
summary(unique_customers)
```

```
##       Age            Gender        AnnualIncome    NumberOfPurchases
##  Min.   :18.00   Min.   :0.0000   Min.   : 20002   Min.   : 0.00
##  1st Qu.:30.75   1st Qu.:0.0000   1st Qu.: 53767   1st Qu.: 6.00
##  Median :44.00   Median :1.0000   Median : 84625   Median :11.00
##  Mean   :43.94   Mean   :0.5014   Mean   : 84699   Mean   :10.55
##  3rd Qu.:57.00   3rd Qu.:1.0000   3rd Qu.:117188   3rd Qu.:15.00
##  Max.   :70.00   Max.   :1.0000   Max.   :149785   Max.   :20.00
##  ProductCategory TimeSpentOnWebsite LoyaltyProgram   DiscountsAvailed
##  Min.   :0.000   Min.   : 1.037     Min.   :0.0000   Min.   :0.00
##  1st Qu.:1.000   1st Qu.:16.380     1st Qu.:0.0000   1st Qu.:1.00
##  Median :2.000   Median :31.213     Median :0.0000   Median :3.00
##  Mean   :2.003   Mean   :30.748     Mean   :0.3336   Mean   :2.61
##  3rd Qu.:3.000   3rd Qu.:44.666     3rd Qu.:1.0000   3rd Qu.:4.00
##  Max.   :4.000   Max.   :59.991     Max.   :1.0000   Max.   :5.00
##  PurchaseStatus
##  Min.   :0.0000
##  1st Qu.:0.0000
##  Median :0.0000
##  Mean   :0.4669
##  3rd Qu.:1.0000
##  Max.   :1.0000
```

```r
BreakPointsDiscounts <- c(2)
BreakPointsTimeSpent <- c(-Inf, 29, Inf)
breakpoints <- c(-Inf, 40, Inf)

unique_customers <- unique_customers%>%
  mutate(
    Gender = as.factor(unique_customers$Gender),
    ProductCategory = as.factor(unique_customers$ProductCategory),
    LoyaltyProgram = as.factor(unique_customers$LoyaltyProgram),
    PurchaseStatus = factor(unique_customers$PurchaseStatus,levels = c(1, 0),labels = c("Yes", "No")),
    AnnualIncome = log(unique_customers$AnnualIncome),
    LoyaltyDiscInteraction = as.integer(unique_customers$LoyaltyProgram)*unique_customers$DiscountsAvail
    CatDiscountsAvailed = cut(unique_customers$DiscountsAvailed,
                              breaks = BreakPointsDiscounts,
                              labels = as.factor(c('Low Discounts Availed', 'High Discounts Availed')))
```

```
  )

glimpse(unique_customers)
```

```
## Rows: 1,388
## Columns: 11
## $ Age                     <int> 40, 20, 27, 24, 31, 66, 39, 64, 43, 20, 66, 70,~
## $ Gender                  <fct> 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1, 1,~
## $ AnnualIncome            <dbl> 11.09923, 10.06814, 11.75839, 11.83355, 11.5059~
## $ NumberOfPurchases       <int> 8, 4, 11, 19, 19, 14, 16, 13, 20, 16, 11, 11, 9~
## $ ProductCategory         <fct> 0, 2, 2, 3, 1, 4, 3, 2, 1, 0, 1, 2, 2, 0, 1, 4,~
## $ TimeSpentOnWebsite      <dbl> 30.568601, 38.240097, 31.633212, 46.167059, 19.~
## $ LoyaltyProgram          <fct> 0, 0, 1, 0, 0, 0, 1, 1, 0, 0, 1, 0, 1, 1, 1, 0,~
## $ DiscountsAvailed        <int> 5, 5, 0, 4, 0, 2, 4, 0, 3, 5, 5, 4, 5, 1, 4, 0,~
## $ PurchaseStatus          <fct> Yes, No, Yes, Yes, Yes, No, Yes, No, No, Yes, Y~
## $ LoyaltyDiscInteraction <int> 0, 0, 0, 0, 0, 0, 4, 0, 0, 0, 5, 0, 5, 1, 4, 0,~
## $ CatDiscountsAvailed     <fct> High Discounts Availed, High Discounts Availed,~
```

```
set.seed(702)
train_ix = createDataPartition(unique_customers$PurchaseStatus, p=0.8)

unique_customers_train <- unique_customers[train_ix$Resample1,]
unique_customers_test <- unique_customers[-train_ix$Resample1,]
train_ix
```

```
## $Resample1
##    [1]    2    3    5    6    7    9   10   11   12   13   14   15   16   17
##   [15]   18   19   20   21   23   24   25   26   27   28   29   30   31   32
##   [29]   33   34   35   36   37   38   39   41   42   43   44   46   47   48
##   [43]   50   51   53   54   55   56   57   58   59   60   61   63   64   65
##   [57]   66   67   69   70   71   72   73   75   76   77   79   80   81   82
##   [71]   83   84   85   86   87   89   90   91   92   93   96   98   99  101
##   [85]  102  106  107  108  109  110  111  112  113  114  115  116  118  119
##   [99]  120  121  122  123  125  126  128  129  132  133  134  135  136  137
##  [113]  138  139  140  141  142  143  144  145  146  147  148  150  152  154
##  [127]  155  156  158  161  162  163  164  165  166  167  168  169  170  171
##  [141]  172  173  174  175  177  178  179  180  181  182  183  186  187  188
##  [155]  189  190  191  192  193  194  195  196  197  199  200  201  203  204
##  [169]  206  207  209  210  211  214  215  216  217  218  219  220  221  222
##  [183]  224  225  226  227  228  229  230  231  232  233  234  235  236  237
##  [197]  239  242  244  245  248  249  251  252  253  254  255  256  257  258
##  [211]  261  262  263  264  267  268  269  270  271  272  274  276  278  279
##  [225]  280  281  282  283  284  286  287  289  290  291  293  294  295  296
##  [239]  297  300  301  302  303  304  305  306  307  309  310  311  312  313
##  [253]  314  315  317  318  319  320  321  323  324  325  326  328  329  330
##  [267]  331  332  333  335  336  338  340  341  342  343  344  345  346  347
##  [281]  348  349  351  352  353  355  357  358  359  360  361  362  363  364
##  [295]  365  366  367  368  369  370  371  373  375  376  377  378  379  380
##  [309]  381  383  386  387  388  389  390  392  393  395  398  401  402  403
##  [323]  404  407  408  409  410  411  412  413  415  416  417  418  419  420
##  [337]  422  424  425  426  430  431  432  435  436  439  440  442  443  445
##  [351]  447  448  449  450  451  452  453  455  456  457  458  459  460  461
##  [365]  462  463  464  465  466  467  468  469  470  471  472  473  474  475
##  [379]  477  478  479  480  481  482  483  484  485  487  488  489  490  492
```

```
##  [393]  493  494  495  496  497  498  499  500  501  503  505  506  507  508
##  [407]  511  513  514  516  517  519  520  521  522  523  525  526  527  528
##  [421]  532  533  534  535  536  537  538  539  540  541  542  543  545  546
##  [435]  547  548  549  550  551  552  553  555  556  557  558  559  560  561
##  [449]  562  563  564  565  567  568  569  570  571  572  573  574  575  576
##  [463]  577  579  583  585  586  587  588  589  590  591  592  593  594  595
##  [477]  596  597  598  599  600  601  603  604  605  606  607  608  609  611
##  [491]  612  613  614  615  616  617  618  620  621  622  623  624  625  627
##  [505]  628  629  632  633  634  635  636  638  639  642  644  645  646  647
##  [519]  648  649  650  653  656  657  658  659  660  661  662  664  665  666
##  [533]  667  668  669  670  671  672  674  677  678  680  681  682  685  686
##  [547]  687  689  690  691  692  693  695  699  700  701  703  704  705  707
##  [561]  709  711  712  713  715  716  718  720  721  722  723  724  726  727
##  [575]  728  729  730  731  732  734  735  736  737  738  739  740  741  742
##  [589]  743  746  747  748  749  751  752  753  754  755  757  758  759  760
##  [603]  761  762  763  764  765  767  768  769  771  772  773  774  775  776
##  [617]  777  780  781  782  783  784  786  787  788  790  791  792  795  798
##  [631]  799  800  801  804  805  806  807  808  809  810  811  812  813  814
##  [645]  816  818  819  820  821  823  824  825  826  827  832  833  834  835
##  [659]  836  837  839  840  842  843  845  846  848  849  850  851  852  856
##  [673]  857  859  860  861  862  863  865  866  867  868  869  870  871  872
##  [687]  873  874  875  877  878  881  882  883  884  885  886  887  888  889
##  [701]  890  891  892  893  894  895  896  897  899  900  901  902  903  904
##  [715]  905  906  907  908  909  911  912  913  914  915  916  917  918  919
##  [729]  920  921  923  925  926  927  928  929  930  931  933  935  937  938
##  [743]  940  942  944  946  947  948  949  950  953  954  955  956  957  958
##  [757]  959  960  961  962  963  965  966  967  968  969  970  971  972  973
##  [771]  974  976  977  978  979  980  982  983  984  985  986  987  988  990
##  [785]  991  992  993  994  995  996  997  998  999 1000 1001 1002 1003 1004
##  [799] 1005 1006 1007 1008 1009 1010 1011 1012 1013 1015 1016 1017 1018 1019
##  [813] 1020 1021 1022 1023 1024 1025 1026 1027 1029 1030 1031 1032 1033 1034
##  [827] 1035 1036 1037 1038 1039 1040 1041 1042 1043 1044 1045 1047 1048 1049
##  [841] 1052 1053 1054 1056 1057 1058 1059 1062 1065 1066 1067 1068 1069 1071
##  [855] 1072 1073 1074 1075 1076 1077 1079 1080 1082 1083 1084 1085 1086 1087
##  [869] 1088 1091 1092 1093 1094 1095 1096 1097 1098 1099 1101 1103 1104 1105
##  [883] 1106 1108 1109 1110 1112 1113 1114 1115 1117 1118 1119 1120 1121 1122
##  [897] 1123 1124 1125 1126 1128 1129 1130 1132 1133 1134 1135 1137 1140 1141
##  [911] 1142 1143 1144 1145 1146 1147 1148 1149 1152 1153 1154 1155 1156 1158
##  [925] 1161 1162 1163 1164 1165 1168 1170 1172 1173 1174 1175 1176 1177 1178
##  [939] 1179 1180 1181 1182 1183 1184 1185 1186 1188 1189 1190 1191 1195 1196
##  [953] 1197 1198 1199 1200 1201 1203 1204 1205 1207 1208 1209 1210 1211 1212
##  [967] 1213 1214 1215 1216 1217 1218 1219 1220 1222 1223 1224 1226 1227 1228
##  [981] 1229 1230 1231 1232 1233 1234 1235 1236 1237 1238 1239 1242 1243 1244
##  [995] 1245 1246 1247 1249 1250 1251 1253 1254 1255 1256 1257 1258 1259 1260
## [1009] 1262 1263 1264 1266 1267 1268 1269 1270 1273 1275 1277 1278 1279 1280
## [1023] 1281 1282 1283 1284 1285 1286 1287 1289 1290 1291 1292 1293 1294 1295
## [1037] 1296 1298 1299 1300 1301 1302 1305 1306 1308 1309 1310 1311 1312 1313
## [1051] 1314 1316 1317 1318 1319 1321 1322 1324 1325 1326 1327 1328 1330 1331
## [1065] 1334 1335 1336 1338 1339 1341 1343 1344 1345 1347 1348 1349 1350 1351
## [1079] 1352 1353 1355 1356 1358 1359 1360 1361 1362 1363 1364 1365 1366 1367
## [1093] 1368 1370 1371 1372 1373 1375 1376 1377 1378 1379 1380 1381 1382 1383
## [1107] 1384 1385 1386 1387 1388
```

```r
set.seed(702)
kcv <- 10
cv_folds <- createFolds(unique_customers_train$PurchaseStatus,
                        k = kcv)

my_summary = function(data, lev = NULL, model = NULL){
  default = defaultSummary(data, lev, model)
  twoclass = twoClassSummary(data, lev, model)

  twoclass[3] = 1 - twoclass[3]
  names(twoclass) = c('AUC_ROC', 'TPR', 'FPR')
  logloss = mnLogLoss(data, lev, model)
  c(default, twoclass, logloss)
}

fit_control <- trainControl(
  method = 'cv',
  indexOut = cv_folds,

  classProbs = TRUE,
  savePredictions = TRUE,
  summaryFunction = my_summary,
  selectionFunction = 'oneSE'
)
```

```r
set.seed(702)
gbm_grid <- expand.grid(
  interaction.depth= c(7, 10, 12),
  n.trees = c(100,150,200,300),
  shrinkage = c(0.15, 0.2, 0.25),
  n.minobsinnode = c(5,7,10)
)

gbmfit <- train(
  PurchaseStatus~.-ProductCategory, data = unique_customers_train,
  method = 'gbm',
  trControl = fit_control,
  tuneGrid = gbm_grid,
  metric = 'logLoss',
  verbose = FALSE
)

gbmfit
```

```
## Stochastic Gradient Boosting
##
## 1111 samples
##   10 predictor
##    2 classes: 'Yes', 'No'
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
## Summary of sample sizes: 999, 1000, 1000, 1000, 999, 1000, ...
## Resampling results across tuning parameters:
```

```
##
##   shrinkage  interaction.depth  n.minobsinnode  n.trees  Accuracy   Kappa
##   0.15        7                  5              100      0.9684841  0.9366671
##   0.15        7                  5              150      0.9856094  0.9711085
##   0.15        7                  5              200      0.9919159  0.9837862
##   0.15        7                  5              300      0.9918998  0.9837441
##   0.15        7                  7              100      0.9639713  0.9276249
##   0.15        7                  7              150      0.9801960  0.9602355
##   0.15        7                  7              200      0.9900978  0.9801305
##   0.15        7                  7              300      0.9910069  0.9819511
##   0.15        7                 10              100      0.9639552  0.9275851
##   0.15        7                 10              150      0.9756752  0.9511862
##   0.15        7                 10              200      0.9882881  0.9765016
##   0.15        7                 10              300      0.9918917  0.9837252
##   0.15       10                  5              100      0.9846763  0.9692354
##   0.15       10                  5              150      0.9927845  0.9855047
##   0.15       10                  5              200      0.9927926  0.9855239
##   0.15       10                  5              300      0.9927926  0.9855239
##   0.15       10                  7              100      0.9810967  0.9620725
##   0.15       10                  7              150      0.9909907  0.9819134
##   0.15       10                  7              200      0.9937016  0.9873617
##   0.15       10                  7              300      0.9937016  0.9873617
##   0.15       10                 10              100      0.9810806  0.9620217
##   0.15       10                 10              150      0.9945944  0.9891501
##   0.15       10                 10              200      0.9918998  0.9837354
##   0.15       10                 10              300      0.9928007  0.9855506
##   0.15       12                  5              100      0.9918998  0.9837354
##   0.15       12                  5              150      0.9936935  0.9873473
##   0.15       12                  5              200      0.9936935  0.9873432
##   0.15       12                  5              300      0.9936935  0.9873432
##   0.15       12                  7              100      0.9900818  0.9801018
##   0.15       12                  7              150      0.9936935  0.9873390
##   0.15       12                  7              200      0.9936935  0.9873473
##   0.15       12                  7              300      0.9928007  0.9855593
##   0.15       12                 10              100      0.9882880  0.9764802
##   0.15       12                 10              150      0.9909989  0.9819409
##   0.15       12                 10              200      0.9918998  0.9837437
##   0.15       12                 10              300      0.9927926  0.9855363
##   0.20        7                  5              100      0.9774931  0.9548393
##   0.20        7                  5              150      0.9900818  0.9800962
##   0.20        7                  5              200      0.9936935  0.9873514
##   0.20        7                  5              300      0.9928007  0.9855589
##   0.20        7                  7              100      0.9792788  0.9583955
##   0.20        7                  7              150      0.9918916  0.9837245
##   0.20        7                  7              200      0.9928007  0.9855547
##   0.20        7                  7              300      0.9928007  0.9855547
##   0.20        7                 10              100      0.9702697  0.9402135
##   0.20        7                 10              150      0.9873791  0.9746466
##   0.20        7                 10              200      0.9918917  0.9837252
##   0.20        7                 10              300      0.9918917  0.9837293
##   0.20       10                  5              100      0.9891889  0.9782826
##   0.20       10                  5              150      0.9918998  0.9837391
##   0.20       10                  5              200      0.9936935  0.9873473
##   0.20       10                  5              300      0.9928007  0.9855547
```

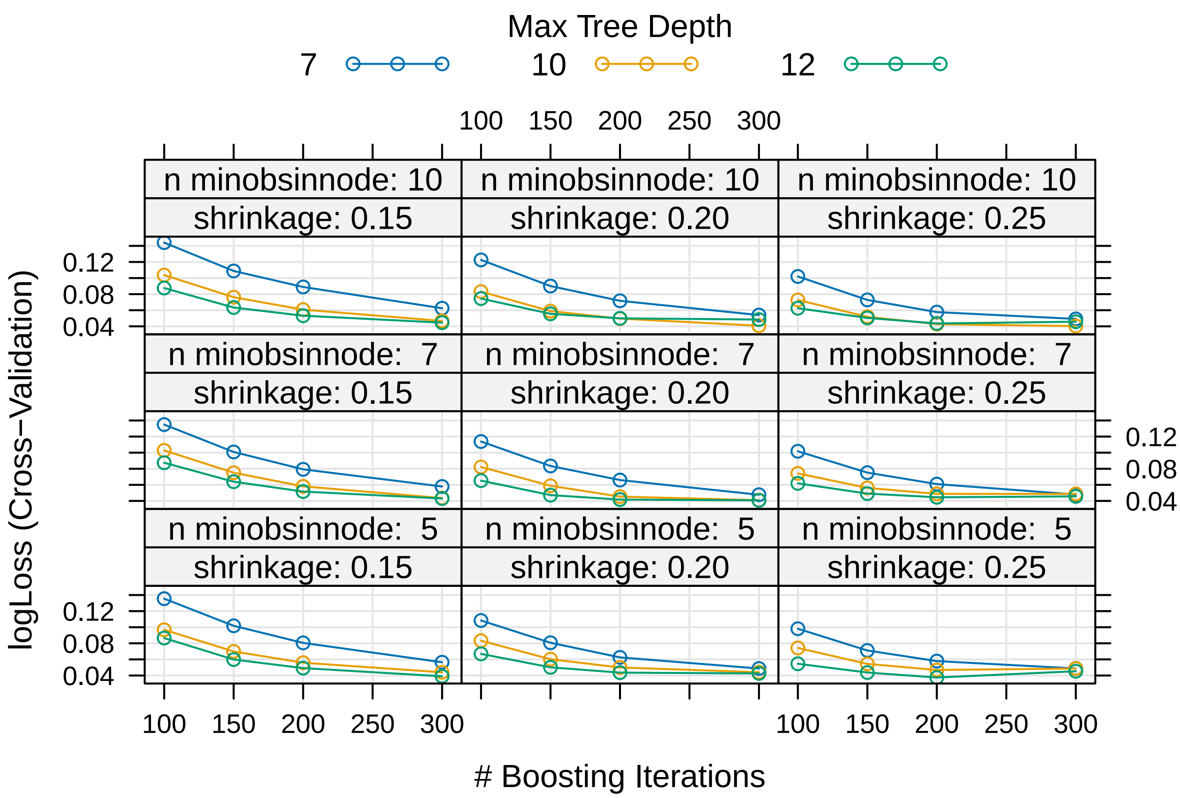
```
##   0.20       10                 7            100       0.9909987  0.9819365
##   0.20       10                 7            150       0.9936935  0.9873390
##   0.20       10                 7            200       0.9936935  0.9873390
##   0.20       10                 7            300       0.9936935  0.9873473
##   0.20       10                10            100       0.9873951  0.9747087
##   0.20       10                10            150       0.9918998  0.9837395
##   0.20       10                10            200       0.9937016  0.9873493
##   0.20       10                10            300       0.9945944  0.9891419
##   0.20       12                 5            100       0.9928007  0.9855465
##   0.20       12                 5            150       0.9937016  0.9873576
##   0.20       12                 5            200       0.9928007  0.9855547
##   0.20       12                 5            300       0.9928007  0.9855424
##   0.20       12                 7            100       0.9918998  0.9837350
##   0.20       12                 7            150       0.9927926  0.9855321
##   0.20       12                 7            200       0.9927926  0.9855321
##   0.20       12                 7            300       0.9927926  0.9855321
##   0.20       12                10            100       0.9892051  0.9783203
##   0.20       12                10            150       0.9874033  0.9747022
##   0.20       12                10            200       0.9882962  0.9764948
##   0.20       12                10            300       0.9892051  0.9783161
##   0.25        7                 5            100       0.9856014  0.9711015
##   0.25        7                 5            150       0.9909989  0.9819326
##   0.25        7                 5            200       0.9901060  0.9801355
##   0.25        7                 5            300       0.9901060  0.9801355
##   0.25        7                 7            100       0.9855933  0.9710742
##   0.25        7                 7            150       0.9909989  0.9819367
##   0.25        7                 7            200       0.9928007  0.9855547
##   0.25        7                 7            300       0.9928007  0.9855547
##   0.25        7                10            100       0.9819979  0.9638781
##   0.25        7                10            150       0.9918998  0.9837354
##   0.25        7                10            200       0.9918998  0.9837437
##   0.25        7                10            300       0.9937016  0.9873617
##   0.25       10                 5            100       0.9936935  0.9873473
##   0.25       10                 5            150       0.9918917  0.9837252
##   0.25       10                 5            200       0.9936935  0.9873432
##   0.25       10                 5            300       0.9928007  0.9855552
##   0.25       10                 7            100       0.9918998  0.9837441
##   0.25       10                 7            150       0.9919078  0.9837668
##   0.25       10                 7            200       0.9919078  0.9837668
##   0.25       10                 7            300       0.9910069  0.9819598
##   0.25       10                10            100       0.9918917  0.9837252
##   0.25       10                10            150       0.9928007  0.9855460
##   0.25       10                10            200       0.9937016  0.9873530
##   0.25       10                10            300       0.9918998  0.9837350
##   0.25       12                 5            100       0.9927926  0.9855321
##   0.25       12                 5            150       0.9936935  0.9873473
##   0.25       12                 5            200       0.9954873  0.9909468
##   0.25       12                 5            300       0.9936935  0.9873473
##   0.25       12                 7            100       0.9909908  0.9819100
##   0.25       12                 7            150       0.9918917  0.9837169
##   0.25       12                 7            200       0.9936935  0.9873514
##   0.25       12                 7            300       0.9918917  0.9837211
##   0.25       12                10            100       0.9918998  0.9837437
##   0.25       12                10            150       0.9900980  0.9801339
```

```
## 0.25 12 10 200 0.9918998 0.9837478
## 0.25 12 10 300 0.9909908 0.9819265
## AUC_ROC TPR FPR logLoss
## 0.9931578 0.9653469 0.028700565 0.13550407
## 0.9956384 0.9865008 0.015112994 0.10177174
## 0.9963826 0.9980769 0.013446328 0.08055780
## 0.9967744 0.9961538 0.011807910 0.05646836
## 0.9927716 0.9633861 0.035480226 0.13491809
## 0.9958292 0.9826546 0.021920904 0.10086337
## 0.9965149 0.9922700 0.011779661 0.07926730
## 0.9967117 0.9942308 0.011807910 0.05791833
## 0.9903261 0.9633861 0.035480226 0.14406276
## 0.9950489 0.9806938 0.028728814 0.10883694
## 0.9951158 0.9923077 0.015225989 0.08893875
## 0.9961899 0.9942308 0.010141243 0.06251973
## 0.9958292 0.9865385 0.016920904 0.09682422
## 0.9964165 0.9941931 0.008446328 0.06986486
## 0.9964491 0.9942308 0.008446328 0.05591410
## 0.9965143 0.9942308 0.008446328 0.04400189
## 0.9958283 0.9884238 0.025282486 0.10280064
## 0.9961864 0.9941931 0.011807910 0.07505148
## 0.9961555 0.9980769 0.010112994 0.05810891
## 0.9964810 0.9980769 0.010112994 0.04354182
## 0.9949876 0.9845777 0.021949153 0.10371154
## 0.9957059 0.9980769 0.008446328 0.07619878
## 0.9958651 0.9942308 0.010112994 0.06075350
## 0.9958005 0.9961538 0.010112994 0.04671386
## 0.9960259 0.9942308 0.010112994 0.08656299
## 0.9961563 0.9980769 0.010141243 0.05984330
## 0.9961551 0.9961538 0.008446328 0.04920246
## 0.9966114 0.9961538 0.008446328 0.03900934
## 0.9950475 0.9961538 0.015225989 0.08746366
## 0.9951464 0.9961538 0.008446328 0.06391157
## 0.9955369 0.9980769 0.010141243 0.05162764
## 0.9961581 0.9980769 0.011807910 0.04300183
## 0.9959650 0.9903469 0.013502825 0.08759585
## 0.9958998 0.9961538 0.013502825 0.06339739
## 0.9958661 0.9961538 0.011807910 0.05323300
## 0.9965148 0.9961538 0.010141243 0.04456562
## 0.9949843 0.9826546 0.027005650 0.10836121
## 0.9963857 0.9941931 0.013531073 0.08069818
## 0.9962541 0.9980769 0.010141243 0.06250534
## 0.9963186 0.9980769 0.011807910 0.04868015
## 0.9944719 0.9807315 0.021949153 0.11383441
## 0.9959642 0.9961161 0.011807910 0.08344272
## 0.9961603 0.9980769 0.011807910 0.06593295
## 0.9964503 0.9980769 0.011807910 0.04769340
## 0.9928020 0.9633861 0.023615819 0.12253793
## 0.9952424 0.9865008 0.011836158 0.09003823
## 0.9956999 0.9961538 0.011836158 0.07174845
## 0.9956017 0.9961538 0.011836158 0.05402108
## 0.9951814 0.9865008 0.008446328 0.08322281
## 0.9959926 0.9942308 0.010141243 0.06021954
## 0.9959927 0.9980769 0.010141243 0.04997540
```

```
##    0.9961550  0.9980769  0.011807910  0.04406573
##    0.9962881  0.9961161  0.013474576  0.08217529
##    0.9960910  0.9961538  0.008446328  0.05882392
##    0.9964828  0.9961538  0.008446328  0.04532449
##    0.9964152  0.9980769  0.010141243  0.04092821
##    0.9962209  0.9941931  0.018559322  0.08314068
##    0.9965479  0.9961538  0.011807910  0.05889590
##    0.9965473  0.9961538  0.008418079  0.04962793
##    0.9966440  0.9961538  0.006751412  0.04076310
##    0.9960887  0.9961538  0.010112994  0.06688664
##    0.9959588  0.9980769  0.010112994  0.05015860
##    0.9961876  0.9980769  0.011807910  0.04357248
##    0.9962842  0.9961538  0.010112994  0.04259100
##    0.9964574  0.9923077  0.008446328  0.06521359
##    0.9967460  0.9942308  0.008446328  0.04723201
##    0.9963885  0.9942308  0.008446328  0.04168658
##    0.9964520  0.9942308  0.008446328  0.04068586
##    0.9958296  0.9903846  0.011807910  0.07454577
##    0.9959274  0.9884615  0.013502825  0.05556379
##    0.9958949  0.9884615  0.011836158  0.04994822
##    0.9960916  0.9903846  0.011807910  0.04847732
##    0.9952161  0.9903469  0.018531073  0.09812685
##    0.9959625  0.9942308  0.011807910  0.07110021
##    0.9960911  0.9923077  0.011807910  0.05789867
##    0.9962867  0.9923077  0.011807910  0.04877690
##    0.9949483  0.9884238  0.016864407  0.10172616
##    0.9955086  0.9961538  0.013502825  0.07513621
##    0.9961871  0.9980769  0.011807910  0.06090906
##    0.9964152  0.9980769  0.011807910  0.04791231
##    0.9947992  0.9884615  0.023644068  0.10198085
##    0.9958764  0.9961538  0.011807910  0.07282870
##    0.9963578  0.9961538  0.011807910  0.05767433
##    0.9962854  0.9980769  0.010112994  0.04922581
##    0.9944375  0.9980769  0.010141243  0.07424330
##    0.9954763  0.9961538  0.011836158  0.05444465
##    0.9961243  0.9980769  0.010141243  0.04689647
##    0.9961922  0.9980769  0.011807910  0.04866062
##    0.9957346  0.9961538  0.011807910  0.07419453
##    0.9955352  0.9980769  0.013474576  0.05617536
##    0.9959589  0.9980769  0.013474576  0.04876241
##    0.9955671  0.9980769  0.015169492  0.04872267
##    0.9955677  0.9961538  0.011836158  0.07278096
##    0.9962528  0.9961538  0.010141243  0.05187597
##    0.9962535  0.9961538  0.008446328  0.04275905
##    0.9963519  0.9942308  0.010141243  0.04033936
##    0.9958969  0.9961538  0.010141243  0.05458979
##    0.9954393  0.9980769  0.010141243  0.04370399
##    0.9961238  0.9980769  0.006779661  0.03750566
##    0.9956668  0.9980769  0.010141243  0.04529068
##    0.9951773  0.9923077  0.010141243  0.06183388
##    0.9950482  0.9923077  0.008446328  0.04908034
##    0.9950789  0.9980769  0.010141243  0.04454717
##    0.9953077  0.9942308  0.010141243  0.04563646
##    0.9958028  0.9961538  0.011807910  0.06253578
```

```
##    0.9958989  0.9961538  0.015197740  0.05046673
##    0.9960925  0.9980769  0.013502825  0.04358287
##    0.9961896  0.9961538  0.013531073  0.04573337
##
## logLoss was used to select the optimal model using  the one SE rule.
## The final values used for the model were n.trees = 150, interaction.depth =
##  12, shrinkage = 0.2 and n.minobsinnode = 7.
```

```r
set.seed(702)
plot(gbmfit)
```




```r
set.seed(702)
confusionMatrix(gbmfit)
```

```
## Cross-Validated (10 fold) Confusion Matrix
##
## (entries are percentual average cell counts across resamples)
##
##           Reference
## Prediction  Yes   No
##        Yes 46.4  0.5
##        No   0.3 52.8
##
##  Accuracy (average) : 0.9928
```

```r
set.seed(702)
thresholder(
            gbmfit,
```

```r
             threshold = 0.5,
             final = TRUE,
             statistics = c('Sensitivity',
                            'Specificity')
             )
```

```
##   n.trees interaction.depth shrinkage n.minobsinnode prob_threshold Sensitivity
## 1     150                12       0.2              7            0.5   0.9942308
##   Specificity
## 1   0.9915537
```

```r
set.seed(702)
gbmfit_res = thresholder(gbmfit,
                         threshold = seq(0.0005, 1, by = 0.005),
                         final = TRUE)
gbmfit_res
```

```
##     n.trees interaction.depth shrinkage n.minobsinnode prob_threshold
## 1       150                12       0.2              7         0.0005
## 2       150                12       0.2              7         0.0055
## 3       150                12       0.2              7         0.0105
## 4       150                12       0.2              7         0.0155
## 5       150                12       0.2              7         0.0205
## 6       150                12       0.2              7         0.0255
## 7       150                12       0.2              7         0.0305
## 8       150                12       0.2              7         0.0355
## 9       150                12       0.2              7         0.0405
## 10      150                12       0.2              7         0.0455
## 11      150                12       0.2              7         0.0505
## 12      150                12       0.2              7         0.0555
## 13      150                12       0.2              7         0.0605
## 14      150                12       0.2              7         0.0655
## 15      150                12       0.2              7         0.0705
## 16      150                12       0.2              7         0.0755
## 17      150                12       0.2              7         0.0805
## 18      150                12       0.2              7         0.0855
## 19      150                12       0.2              7         0.0905
## 20      150                12       0.2              7         0.0955
## 21      150                12       0.2              7         0.1005
## 22      150                12       0.2              7         0.1055
## 23      150                12       0.2              7         0.1105
## 24      150                12       0.2              7         0.1155
## 25      150                12       0.2              7         0.1205
## 26      150                12       0.2              7         0.1255
## 27      150                12       0.2              7         0.1305
## 28      150                12       0.2              7         0.1355
## 29      150                12       0.2              7         0.1405
## 30      150                12       0.2              7         0.1455
## 31      150                12       0.2              7         0.1505
## 32      150                12       0.2              7         0.1555
## 33      150                12       0.2              7         0.1605
## 34      150                12       0.2              7         0.1655
## 35      150                12       0.2              7         0.1705
## 36      150                12       0.2              7         0.1755
## 37      150                12       0.2              7         0.1805
```

```
## 38       150               12       0.2            7          0.1855
## 39       150               12       0.2            7          0.1905
## 40       150               12       0.2            7          0.1955
## 41       150               12       0.2            7          0.2005
## 42       150               12       0.2            7          0.2055
## 43       150               12       0.2            7          0.2105
## 44       150               12       0.2            7          0.2155
## 45       150               12       0.2            7          0.2205
## 46       150               12       0.2            7          0.2255
## 47       150               12       0.2            7          0.2305
## 48       150               12       0.2            7          0.2355
## 49       150               12       0.2            7          0.2405
## 50       150               12       0.2            7          0.2455
## 51       150               12       0.2            7          0.2505
## 52       150               12       0.2            7          0.2555
## 53       150               12       0.2            7          0.2605
## 54       150               12       0.2            7          0.2655
## 55       150               12       0.2            7          0.2705
## 56       150               12       0.2            7          0.2755
## 57       150               12       0.2            7          0.2805
## 58       150               12       0.2            7          0.2855
## 59       150               12       0.2            7          0.2905
## 60       150               12       0.2            7          0.2955
## 61       150               12       0.2            7          0.3005
## 62       150               12       0.2            7          0.3055
## 63       150               12       0.2            7          0.3105
## 64       150               12       0.2            7          0.3155
## 65       150               12       0.2            7          0.3205
## 66       150               12       0.2            7          0.3255
## 67       150               12       0.2            7          0.3305
## 68       150               12       0.2            7          0.3355
## 69       150               12       0.2            7          0.3405
## 70       150               12       0.2            7          0.3455
## 71       150               12       0.2            7          0.3505
## 72       150               12       0.2            7          0.3555
## 73       150               12       0.2            7          0.3605
## 74       150               12       0.2            7          0.3655
## 75       150               12       0.2            7          0.3705
## 76       150               12       0.2            7          0.3755
## 77       150               12       0.2            7          0.3805
## 78       150               12       0.2            7          0.3855
## 79       150               12       0.2            7          0.3905
## 80       150               12       0.2            7          0.3955
## 81       150               12       0.2            7          0.4005
## 82       150               12       0.2            7          0.4055
## 83       150               12       0.2            7          0.4105
## 84       150               12       0.2            7          0.4155
## 85       150               12       0.2            7          0.4205
## 86       150               12       0.2            7          0.4255
## 87       150               12       0.2            7          0.4305
## 88       150               12       0.2            7          0.4355
## 89       150               12       0.2            7          0.4405
## 90       150               12       0.2            7          0.4455
## 91       150               12       0.2            7          0.4505
```

```
## 92      150                 12       0.2               7          0.4555
## 93      150                 12       0.2               7          0.4605
## 94      150                 12       0.2               7          0.4655
## 95      150                 12       0.2               7          0.4705
## 96      150                 12       0.2               7          0.4755
## 97      150                 12       0.2               7          0.4805
## 98      150                 12       0.2               7          0.4855
## 99      150                 12       0.2               7          0.4905
## 100     150                 12       0.2               7          0.4955
## 101     150                 12       0.2               7          0.5005
## 102     150                 12       0.2               7          0.5055
## 103     150                 12       0.2               7          0.5105
## 104     150                 12       0.2               7          0.5155
## 105     150                 12       0.2               7          0.5205
## 106     150                 12       0.2               7          0.5255
## 107     150                 12       0.2               7          0.5305
## 108     150                 12       0.2               7          0.5355
## 109     150                 12       0.2               7          0.5405
## 110     150                 12       0.2               7          0.5455
## 111     150                 12       0.2               7          0.5505
## 112     150                 12       0.2               7          0.5555
## 113     150                 12       0.2               7          0.5605
## 114     150                 12       0.2               7          0.5655
## 115     150                 12       0.2               7          0.5705
## 116     150                 12       0.2               7          0.5755
## 117     150                 12       0.2               7          0.5805
## 118     150                 12       0.2               7          0.5855
## 119     150                 12       0.2               7          0.5905
## 120     150                 12       0.2               7          0.5955
## 121     150                 12       0.2               7          0.6005
## 122     150                 12       0.2               7          0.6055
## 123     150                 12       0.2               7          0.6105
## 124     150                 12       0.2               7          0.6155
## 125     150                 12       0.2               7          0.6205
## 126     150                 12       0.2               7          0.6255
## 127     150                 12       0.2               7          0.6305
## 128     150                 12       0.2               7          0.6355
## 129     150                 12       0.2               7          0.6405
## 130     150                 12       0.2               7          0.6455
## 131     150                 12       0.2               7          0.6505
## 132     150                 12       0.2               7          0.6555
## 133     150                 12       0.2               7          0.6605
## 134     150                 12       0.2               7          0.6655
## 135     150                 12       0.2               7          0.6705
## 136     150                 12       0.2               7          0.6755
## 137     150                 12       0.2               7          0.6805
## 138     150                 12       0.2               7          0.6855
## 139     150                 12       0.2               7          0.6905
## 140     150                 12       0.2               7          0.6955
## 141     150                 12       0.2               7          0.7005
## 142     150                 12       0.2               7          0.7055
## 143     150                 12       0.2               7          0.7105
## 144     150                 12       0.2               7          0.7155
## 145     150                 12       0.2               7          0.7205
```

```
## 146      150                12        0.2               7          0.7255
## 147      150                12        0.2               7          0.7305
## 148      150                12        0.2               7          0.7355
## 149      150                12        0.2               7          0.7405
## 150      150                12        0.2               7          0.7455
## 151      150                12        0.2               7          0.7505
## 152      150                12        0.2               7          0.7555
## 153      150                12        0.2               7          0.7605
## 154      150                12        0.2               7          0.7655
## 155      150                12        0.2               7          0.7705
## 156      150                12        0.2               7          0.7755
## 157      150                12        0.2               7          0.7805
## 158      150                12        0.2               7          0.7855
## 159      150                12        0.2               7          0.7905
## 160      150                12        0.2               7          0.7955
## 161      150                12        0.2               7          0.8005
## 162      150                12        0.2               7          0.8055
## 163      150                12        0.2               7          0.8105
## 164      150                12        0.2               7          0.8155
## 165      150                12        0.2               7          0.8205
## 166      150                12        0.2               7          0.8255
## 167      150                12        0.2               7          0.8305
## 168      150                12        0.2               7          0.8355
## 169      150                12        0.2               7          0.8405
## 170      150                12        0.2               7          0.8455
## 171      150                12        0.2               7          0.8505
## 172      150                12        0.2               7          0.8555
## 173      150                12        0.2               7          0.8605
## 174      150                12        0.2               7          0.8655
## 175      150                12        0.2               7          0.8705
## 176      150                12        0.2               7          0.8755
## 177      150                12        0.2               7          0.8805
## 178      150                12        0.2               7          0.8855
## 179      150                12        0.2               7          0.8905
## 180      150                12        0.2               7          0.8955
## 181      150                12        0.2               7          0.9005
## 182      150                12        0.2               7          0.9055
## 183      150                12        0.2               7          0.9105
## 184      150                12        0.2               7          0.9155
## 185      150                12        0.2               7          0.9205
## 186      150                12        0.2               7          0.9255
## 187      150                12        0.2               7          0.9305
## 188      150                12        0.2               7          0.9355
## 189      150                12        0.2               7          0.9405
## 190      150                12        0.2               7          0.9455
## 191      150                12        0.2               7          0.9505
## 192      150                12        0.2               7          0.9555
## 193      150                12        0.2               7          0.9605
## 194      150                12        0.2               7          0.9655
## 195      150                12        0.2               7          0.9705
## 196      150                12        0.2               7          0.9755
## 197      150                12        0.2               7          0.9805
## 198      150                12        0.2               7          0.9855
## 199      150                12        0.2               7          0.9905
```

```
## 200     150             12       0.2            7        0.9955
##     Sensitivity Specificity Pos Pred Value Neg Pred Value Precision    Recall
## 1     1.0000000   0.1233333      0.5004307      1.0000000 0.5004307 1.0000000
## 2     0.9980769   0.4140678      0.5994710      0.9966667 0.5994710 0.9980769
## 3     0.9980769   0.5373446      0.6549348      0.9971429 0.6549348 0.9980769
## 4     0.9980769   0.6420904      0.7104848      0.9975000 0.7104848 0.9980769
## 5     0.9980769   0.6927119      0.7407034      0.9975610 0.7407034 0.9980769
## 6     0.9980769   0.7400000      0.7716624      0.9978723 0.7716624 0.9980769
## 7     0.9980769   0.7821469      0.8011663      0.9980000 0.8011663 0.9980769
## 8     0.9980769   0.8124859      0.8238176      0.9980000 0.8238176 0.9980769
## 9     0.9980769   0.8327966      0.8398605      0.9980769 0.8398605 0.9980769
## 10    0.9980769   0.8462712      0.8508688      0.9980769 0.8508688 0.9980769
## 11    0.9980769   0.8699435      0.8709118      0.9981481 0.8709118 0.9980769
## 12    0.9980769   0.8868644      0.8858164      0.9981481 0.8858164 0.9980769
## 13    0.9980769   0.9003672      0.8979971      0.9981481 0.8979971 0.9980769
## 14    0.9980769   0.9020621      0.8995948      0.9981818 0.8995948 0.9980769
## 15    0.9980769   0.9122034      0.9091857      0.9981818 0.9091857 0.9980769
## 16    0.9980769   0.9172316      0.9139605      0.9981818 0.9139605 0.9980769
## 17    0.9980769   0.9273729      0.9237723      0.9982456 0.9237723 0.9980769
## 18    0.9980769   0.9324294      0.9286625      0.9982456 0.9286625 0.9980769
## 19    0.9980769   0.9341243      0.9303509      0.9982456 0.9303509 0.9980769
## 20    0.9980769   0.9357910      0.9321017      0.9982456 0.9321017 0.9980769
## 21    0.9980769   0.9374576      0.9337308      0.9982456 0.9337308 0.9980769
## 22    0.9980769   0.9425424      0.9386210      0.9982456 0.9386210 0.9980769
## 23    0.9980769   0.9442373      0.9403094      0.9982456 0.9403094 0.9980769
## 24    0.9980769   0.9510169      0.9472502      0.9982456 0.9472502 0.9980769
## 25    0.9980769   0.9527119      0.9490322      0.9982759 0.9490322 0.9980769
## 26    0.9980769   0.9577966      0.9544816      0.9983051 0.9544816 0.9980769
## 27    0.9980769   0.9577966      0.9544816      0.9983051 0.9544816 0.9980769
## 28    0.9980769   0.9594633      0.9561699      0.9983051 0.9561699 0.9980769
## 29    0.9980769   0.9611582      0.9579207      0.9983051 0.9579207 0.9980769
## 30    0.9980769   0.9628531      0.9595498      0.9983051 0.9595498 0.9980769
## 31    0.9980769   0.9645480      0.9612381      0.9983051 0.9612381 0.9980769
## 32    0.9980769   0.9679096      0.9648394      0.9983051 0.9648394 0.9980769
## 33    0.9980769   0.9679096      0.9648394      0.9983051 0.9648394 0.9980769
## 34    0.9980769   0.9679096      0.9648394      0.9983051 0.9648394 0.9980769
## 35    0.9980769   0.9696045      0.9666564      0.9983051 0.9666564 0.9980769
## 36    0.9980769   0.9696045      0.9666564      0.9983051 0.9666564 0.9980769
## 37    0.9980769   0.9712712      0.9684733      0.9983051 0.9684733 0.9980769
## 38    0.9980769   0.9712712      0.9684733      0.9983051 0.9684733 0.9980769
## 39    0.9980769   0.9712712      0.9684733      0.9983051 0.9684733 0.9980769
## 40    0.9980769   0.9729661      0.9702241      0.9983051 0.9702241 0.9980769
## 41    0.9980769   0.9729661      0.9702241      0.9983051 0.9702241 0.9980769
## 42    0.9980769   0.9729661      0.9702241      0.9983051 0.9702241 0.9980769
## 43    0.9980769   0.9729661      0.9702241      0.9983051 0.9702241 0.9980769
## 44    0.9980769   0.9746610      0.9720410      0.9983051 0.9720410 0.9980769
## 45    0.9980769   0.9763559      0.9738579      0.9983051 0.9738579 0.9980769
## 46    0.9980769   0.9763559      0.9738579      0.9983051 0.9738579 0.9980769
## 47    0.9980769   0.9780508      0.9757447      0.9983051 0.9757447 0.9980769
## 48    0.9980769   0.9780508      0.9757447      0.9983051 0.9757447 0.9980769
## 49    0.9980769   0.9780508      0.9757447      0.9983051 0.9757447 0.9980769
## 50    0.9980769   0.9780508      0.9757447      0.9983051 0.9757447 0.9980769
## 51    0.9980769   0.9780508      0.9757447      0.9983051 0.9757447 0.9980769
## 52    0.9961538   0.9780508      0.9756437      0.9965507 0.9756437 0.9961538
```

```
## 53    0.9961538   0.9797458      0.9774257      0.9965809 0.9774257 0.9961538
## 54    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 55    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 56    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 57    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 58    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 59    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 60    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 61    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 62    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 63    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 64    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 65    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 66    0.9961538   0.9814407      0.9793125      0.9965809 0.9793125 0.9961538
## 67    0.9961538   0.9831356      0.9812356      0.9966092 0.9812356 0.9961538
## 68    0.9961538   0.9831356      0.9812356      0.9966092 0.9812356 0.9961538
## 69    0.9961538   0.9831356      0.9812356      0.9966092 0.9812356 0.9961538
## 70    0.9961538   0.9848023      0.9830525      0.9966092 0.9830525 0.9961538
## 71    0.9961538   0.9864972      0.9849030      0.9966384 0.9849030 0.9961538
## 72    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 73    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 74    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 75    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 76    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 77    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 78    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 79    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 80    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 81    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 82    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 83    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 84    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 85    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 86    0.9961538   0.9881638      0.9867898      0.9966384 0.9867898 0.9961538
## 87    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 88    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 89    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 90    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 91    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 92    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 93    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 94    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 95    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 96    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 97    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 98    0.9961538   0.9898588      0.9886766      0.9966384 0.9886766 0.9961538
## 99    0.9942308   0.9898588      0.9886067      0.9949143 0.9886067 0.9942308
## 100   0.9942308   0.9915537      0.9904935      0.9949143 0.9904935 0.9942308
## 101   0.9942308   0.9915537      0.9904935      0.9949143 0.9904935 0.9942308
## 102   0.9942308   0.9915537      0.9904935      0.9949143 0.9904935 0.9942308
## 103   0.9942308   0.9915537      0.9904935      0.9949143 0.9904935 0.9942308
## 104   0.9942308   0.9915537      0.9904935      0.9949143 0.9904935 0.9942308
## 105   0.9942308   0.9915537      0.9904935      0.9949143 0.9904935 0.9942308
## 106   0.9942308   0.9915537      0.9904935      0.9949143 0.9904935 0.9942308
```

```
## 107   0.9942308   0.9915537       0.9904935       0.9949143 0.9904935 0.9942308
## 108   0.9942308   0.9915537       0.9904935       0.9949143 0.9904935 0.9942308
## 109   0.9942308   0.9915537       0.9904935       0.9949143 0.9904935 0.9942308
## 110   0.9942308   0.9915537       0.9904935       0.9949143 0.9904935 0.9942308
## 111   0.9942308   0.9915537       0.9904935       0.9949143 0.9904935 0.9942308
## 112   0.9942308   0.9915537       0.9904935       0.9949143 0.9904935 0.9942308
## 113   0.9942308   0.9915537       0.9904935       0.9949143 0.9904935 0.9942308
## 114   0.9942308   0.9915537       0.9904935       0.9949143 0.9904935 0.9942308
## 115   0.9942308   0.9915537       0.9904935       0.9949143 0.9904935 0.9942308
## 116   0.9942308   0.9915537       0.9904935       0.9949143 0.9904935 0.9942308
## 117   0.9942308   0.9932486       0.9924165       0.9949425 0.9924165 0.9942308
## 118   0.9942308   0.9932486       0.9924165       0.9949425 0.9924165 0.9942308
## 119   0.9942308   0.9932486       0.9924165       0.9949425 0.9924165 0.9942308
## 120   0.9942308   0.9932486       0.9924165       0.9949425 0.9924165 0.9942308
## 121   0.9942308   0.9932486       0.9924165       0.9949425 0.9924165 0.9942308
## 122   0.9942308   0.9932486       0.9924165       0.9949425 0.9924165 0.9942308
## 123   0.9942308   0.9932486       0.9924165       0.9949425 0.9924165 0.9942308
## 124   0.9942308   0.9932486       0.9924165       0.9949425 0.9924165 0.9942308
## 125   0.9942308   0.9932486       0.9924165       0.9949425 0.9924165 0.9942308
## 126   0.9942308   0.9932486       0.9924165       0.9949425 0.9924165 0.9942308
## 127   0.9923077   0.9932486       0.9924165       0.9933032 0.9924165 0.9923077
## 128   0.9923077   0.9932486       0.9924165       0.9933032 0.9924165 0.9923077
## 129   0.9923077   0.9932486       0.9924165       0.9933032 0.9924165 0.9923077
## 130   0.9923077   0.9932486       0.9924165       0.9933032 0.9924165 0.9923077
## 131   0.9923077   0.9932486       0.9924165       0.9933032 0.9924165 0.9923077
## 132   0.9923077   0.9932486       0.9924165       0.9933032 0.9924165 0.9923077
## 133   0.9923077   0.9932486       0.9924165       0.9933032 0.9924165 0.9923077
## 134   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 135   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 136   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 137   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 138   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 139   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 140   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 141   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 142   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 143   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 144   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 145   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 146   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 147   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 148   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 149   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 150   0.9923077   0.9949435       0.9942671       0.9933324 0.9942671 0.9923077
## 151   0.9903846   0.9949435       0.9942671       0.9916657 0.9942671 0.9903846
## 152   0.9903846   0.9949435       0.9942671       0.9916657 0.9942671 0.9903846
## 153   0.9903846   0.9949435       0.9942671       0.9916657 0.9942671 0.9903846
## 154   0.9903846   0.9949435       0.9942671       0.9916657 0.9942671 0.9903846
## 155   0.9903846   0.9949435       0.9942671       0.9916657 0.9942671 0.9903846
## 156   0.9903846   0.9949435       0.9942671       0.9916657 0.9942671 0.9903846
## 157   0.9903846   0.9949435       0.9942671       0.9916657 0.9942671 0.9903846
## 158   0.9903846   0.9949435       0.9942671       0.9916657 0.9942671 0.9903846
## 159   0.9903846   0.9949435       0.9942671       0.9916657 0.9942671 0.9903846
## 160   0.9903846   0.9949435       0.9942671       0.9916657 0.9942671 0.9903846
```

```
## 161   0.9884615   0.9949435      0.9942671      0.9899991 0.9942671 0.9884615
## 162   0.9884615   0.9949435      0.9942671      0.9899991 0.9942671 0.9884615
## 163   0.9884615   0.9949435      0.9942671      0.9899991 0.9942671 0.9884615
## 164   0.9865385   0.9949435      0.9942671      0.9883871 0.9942671 0.9865385
## 165   0.9865385   0.9949435      0.9942671      0.9883871 0.9942671 0.9865385
## 166   0.9865385   0.9949435      0.9942671      0.9883871 0.9942671 0.9865385
## 167   0.9865385   0.9949435      0.9942671      0.9883871 0.9942671 0.9865385
## 168   0.9865385   0.9949435      0.9942671      0.9883871 0.9942671 0.9865385
## 169   0.9846154   0.9949435      0.9942671      0.9868270 0.9942671 0.9846154
## 170   0.9826923   0.9949435      0.9942671      0.9852150 0.9942671 0.9826923
## 171   0.9807692   0.9949435      0.9942671      0.9835483 0.9942671 0.9807692
## 172   0.9807692   0.9949435      0.9942671      0.9835483 0.9942671 0.9807692
## 173   0.9788462   0.9949435      0.9942671      0.9818817 0.9942671 0.9788462
## 174   0.9750000   0.9949435      0.9942671      0.9786576 0.9942671 0.9750000
## 175   0.9711538   0.9949435      0.9942671      0.9754856 0.9942671 0.9711538
## 176   0.9673077   0.9949435      0.9942293      0.9722871 0.9942293 0.9673077
## 177   0.9673077   0.9949435      0.9942293      0.9722871 0.9942293 0.9673077
## 178   0.9634615   0.9949435      0.9942293      0.9692662 0.9942293 0.9634615
## 179   0.9576923   0.9949435      0.9942293      0.9645836 0.9942293 0.9576923
## 180   0.9500000   0.9949435      0.9941538      0.9583089 0.9941538 0.9500000
## 181   0.9423077   0.9949435      0.9940361      0.9521850 0.9940361 0.9423077
## 182   0.9365008   0.9949435      0.9939984      0.9475548 0.9939984 0.9365008
## 183   0.9249623   0.9949435      0.9939559      0.9387572 0.9939559 0.9249623
## 184   0.9230392   0.9949435      0.9939559      0.9373819 0.9939559 0.9230392
## 185   0.9095400   0.9949435      0.9939167      0.9275886 0.9939167 0.9095400
## 186   0.9037707   0.9949435      0.9939167      0.9236184 0.9939167 0.9037707
## 187   0.8941554   0.9949435      0.9939167      0.9166496 0.9939167 0.8941554
## 188   0.8903092   0.9949435      0.9939167      0.9137230 0.9939167 0.8903092
## 189   0.8845023   0.9966102      0.9958759      0.9095394 0.9958759 0.8845023
## 190   0.8671569   0.9966102      0.9957428      0.8972038 0.9957428 0.8671569
## 191   0.8402338   0.9966102      0.9956439      0.8790148 0.9956439 0.8402338
## 192   0.8228507   0.9966102      0.9955005      0.8665825 0.9955005 0.8228507
## 193   0.8016214   0.9966102      0.9953463      0.8526717 0.9953463 0.8016214
## 194   0.7765460   0.9966102      0.9951800      0.8371024 0.9951800 0.7765460
## 195   0.7496229   0.9966102      0.9951800      0.8214699 0.9951800 0.7496229
## 196   0.6955882   0.9983051      0.9972973      0.7906374 0.9972973 0.6955882
## 197   0.6243213   0.9983051      0.9970588      0.7536174 0.9970588 0.6243213
## 198   0.5568627   0.9983051      0.9966667      0.7216671 0.9966667 0.5568627
## 199   0.4797511   0.9983051      0.9960000      0.6874922 0.9960000 0.4797511
## 200   0.3428356   0.9983051      0.9933333      0.6347550 0.9933333 0.3428356
##            F1 Prevalence Detection Rate Detection Prevalence Balanced Accuracy
## 1   0.6669056  0.4671487      0.4671487            0.9343223         0.5616667
## 2   0.7488400  0.4671487      0.4662478            0.7785115         0.7060724
## 3   0.7906158  0.4671487      0.4662478            0.7128089         0.7677108
## 4   0.8298177  0.4671487      0.4662478            0.6570004         0.8200837
## 5   0.8501616  0.4671487      0.4662478            0.6299968         0.8453944
## 6   0.8701512  0.4671487      0.4662478            0.6048034         0.8690385
## 7   0.8886683  0.4671487      0.4662478            0.5823453         0.8901119
## 8   0.9025074  0.4671487      0.4662478            0.5661773         0.9052814
## 9   0.9120511  0.4671487      0.4662478            0.5553500         0.9154368
## 10  0.9185113  0.4671487      0.4662478            0.5481669         0.9221741
## 11  0.9300586  0.4671487      0.4662478            0.5355540         0.9340102
## 12  0.9384870  0.4671487      0.4662478            0.5265530         0.9424707
## 13  0.9453308  0.4671487      0.4662478            0.5193373         0.9492221
```

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## 14  0.9461973  0.4671487      0.4662478               0.5184364            0.9500695
## 15  0.9514518  0.4671487      0.4662478               0.5130309            0.9551402
## 16  0.9540700  0.4671487      0.4662478               0.5103443            0.9576543
## 17  0.9593710  0.4671487      0.4662478               0.5049387            0.9627249
## 18  0.9620218  0.4671487      0.4662478               0.5022441            0.9652532
## 19  0.9629218  0.4671487      0.4662478               0.5013432            0.9661006
## 20  0.9638387  0.4671487      0.4662478               0.5004503            0.9669339
## 21  0.9647222  0.4671487      0.4662478               0.4995574            0.9677673
## 22  0.9673730  0.4671487      0.4662478               0.4968547            0.9703096
## 23  0.9682730  0.4671487      0.4662478               0.4959538            0.9711571
## 24  0.9719238  0.4671487      0.4662478               0.4923502            0.9745469
## 25  0.9728402  0.4671487      0.4662478               0.4914493            0.9753944
## 26  0.9756428  0.4671487      0.4662478               0.4887384            0.9779368
## 27  0.9756428  0.4671487      0.4662478               0.4887384            0.9779368
## 28  0.9765427  0.4671487      0.4662478               0.4878456            0.9787701
## 29  0.9774597  0.4671487      0.4662478               0.4869447            0.9796176
## 30  0.9783431  0.4671487      0.4662478               0.4860438            0.9804650
## 31  0.9792431  0.4671487      0.4662478               0.4851429            0.9813125
## 32  0.9811122  0.4671487      0.4662478               0.4833409            0.9829933
## 33  0.9811122  0.4671487      0.4662478               0.4833409            0.9829933
## 34  0.9811122  0.4671487      0.4662478               0.4833409            0.9829933
## 35  0.9820466  0.4671487      0.4662478               0.4824400            0.9838407
## 36  0.9820466  0.4671487      0.4662478               0.4824400            0.9838407
## 37  0.9829811  0.4671487      0.4662478               0.4815472            0.9846741
## 38  0.9829811  0.4671487      0.4662478               0.4815472            0.9846741
## 39  0.9829811  0.4671487      0.4662478               0.4815472            0.9846741
## 40  0.9838980  0.4671487      0.4662478               0.4806463            0.9855215
## 41  0.9838980  0.4671487      0.4662478               0.4806463            0.9855215
## 42  0.9838980  0.4671487      0.4662478               0.4806463            0.9855215
## 43  0.9838980  0.4671487      0.4662478               0.4806463            0.9855215
## 44  0.9848324  0.4671487      0.4662478               0.4797454            0.9863690
## 45  0.9857668  0.4671487      0.4662478               0.4788445            0.9872164
## 46  0.9857668  0.4671487      0.4662478               0.4788445            0.9872164
## 47  0.9867192  0.4671487      0.4662478               0.4779436            0.9880639
## 48  0.9867192  0.4671487      0.4662478               0.4779436            0.9880639
## 49  0.9867192  0.4671487      0.4662478               0.4779436            0.9880639
## 50  0.9867192  0.4671487      0.4662478               0.4779436            0.9880639
## 51  0.9867192  0.4671487      0.4662478               0.4779436            0.9880639
## 52  0.9857494  0.4671487      0.4653469               0.4770427            0.9871023
## 53  0.9866658  0.4671487      0.4653469               0.4761418            0.9879498
## 54  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 55  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 56  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 57  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 58  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 59  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 60  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 61  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 62  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 63  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 64  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 65  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 66  0.9876182  0.4671487      0.4653469               0.4752409            0.9887973
## 67  0.9885704  0.4671487      0.4653469               0.4743400            0.9896447
```

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## 68  0.9885704  0.4671487      0.4653469             0.4743400           0.9896447
## 69  0.9885704  0.4671487      0.4653469             0.4743400           0.9896447
## 70  0.9895048  0.4671487      0.4653469             0.4734471           0.9904781
## 71  0.9904389  0.4671487      0.4653469             0.4725462           0.9913255
## 72  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 73  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 74  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 75  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 76  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 77  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 78  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 79  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 80  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 81  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 82  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 83  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 84  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 85  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 86  0.9913912  0.4671487      0.4653469             0.4716534           0.9921588
## 87  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 88  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 89  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 90  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 91  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 92  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 93  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 94  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 95  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 96  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 97  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 98  0.9923436  0.4671487      0.4653469             0.4707525           0.9930063
## 99  0.9913733  0.4671487      0.4644460             0.4698516           0.9920448
## 100 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 101 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 102 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 103 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 104 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 105 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 106 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 107 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 108 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 109 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 110 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 111 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 112 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 113 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 114 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 115 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 116 0.9923257  0.4671487      0.4644460             0.4689507           0.9928922
## 117 0.9932779  0.4671487      0.4644460             0.4680498           0.9937397
## 118 0.9932779  0.4671487      0.4644460             0.4680498           0.9937397
## 119 0.9932779  0.4671487      0.4644460             0.4680498           0.9937397
## 120 0.9932779  0.4671487      0.4644460             0.4680498           0.9937397
## 121 0.9932779  0.4671487      0.4644460             0.4680498           0.9937397
```

```
## 122 0.9932779  0.4671487      0.4644460            0.4680498         0.9937397
## 123 0.9932779  0.4671487      0.4644460            0.4680498         0.9937397
## 124 0.9932779  0.4671487      0.4644460            0.4680498         0.9937397
## 125 0.9932779  0.4671487      0.4644460            0.4680498         0.9937397
## 126 0.9932779  0.4671487      0.4644460            0.4680498         0.9937397
## 127 0.9923070  0.4671487      0.4635531            0.4671569         0.9927781
## 128 0.9923070  0.4671487      0.4635531            0.4671569         0.9927781
## 129 0.9923070  0.4671487      0.4635531            0.4671569         0.9927781
## 130 0.9923070  0.4671487      0.4635531            0.4671569         0.9927781
## 131 0.9923070  0.4671487      0.4635531            0.4671569         0.9927781
## 132 0.9923070  0.4671487      0.4635531            0.4671569         0.9927781
## 133 0.9923070  0.4671487      0.4635531            0.4671569         0.9927781
## 134 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 135 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 136 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 137 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 138 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 139 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 140 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 141 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 142 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 143 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 144 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 145 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 146 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 147 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 148 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 149 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 150 0.9932410  0.4671487      0.4635531            0.4662560         0.9936256
## 151 0.9922702  0.4671487      0.4626522            0.4653551         0.9926641
## 152 0.9922702  0.4671487      0.4626522            0.4653551         0.9926641
## 153 0.9922702  0.4671487      0.4626522            0.4653551         0.9926641
## 154 0.9922702  0.4671487      0.4626522            0.4653551         0.9926641
## 155 0.9922702  0.4671487      0.4626522            0.4653551         0.9926641
## 156 0.9922702  0.4671487      0.4626522            0.4653551         0.9926641
## 157 0.9922702  0.4671487      0.4626522            0.4653551         0.9926641
## 158 0.9922702  0.4671487      0.4626522            0.4653551         0.9926641
## 159 0.9922702  0.4671487      0.4626522            0.4653551         0.9926641
## 160 0.9922702  0.4671487      0.4626522            0.4653551         0.9926641
## 161 0.9912993  0.4671487      0.4617513            0.4644542         0.9917025
## 162 0.9912993  0.4671487      0.4617513            0.4644542         0.9917025
## 163 0.9912993  0.4671487      0.4617513            0.4644542         0.9917025
## 164 0.9903094  0.4671487      0.4608504            0.4635533         0.9907410
## 165 0.9903094  0.4671487      0.4608504            0.4635533         0.9907410
## 166 0.9903094  0.4671487      0.4608504            0.4635533         0.9907410
## 167 0.9903094  0.4671487      0.4608504            0.4635533         0.9907410
## 168 0.9903094  0.4671487      0.4608504            0.4635533         0.9907410
## 169 0.9892999  0.4671487      0.4599495            0.4626524         0.9897794
## 170 0.9883100  0.4671487      0.4590486            0.4617515         0.9888179
## 171 0.9873391  0.4671487      0.4581477            0.4608506         0.9878564
## 172 0.9873391  0.4671487      0.4581477            0.4608506         0.9878564
## 173 0.9863682  0.4671487      0.4572468            0.4599497         0.9868948
## 174 0.9843884  0.4671487      0.4554450            0.4581479         0.9849718
## 175 0.9823890  0.4671487      0.4536432            0.4563461         0.9830487
```

```
## 176 0.9803899  0.4671487      0.4518414           0.4545443          0.9811256
## 177 0.9803899  0.4671487      0.4518414           0.4545443          0.9811256
## 178 0.9783305  0.4671487      0.4500396           0.4527425          0.9792025
## 179 0.9753014  0.4671487      0.4473369           0.4500398          0.9763179
## 180 0.9712617  0.4671487      0.4437414           0.4464442          0.9724718
## 181 0.9671624  0.4671487      0.4401539           0.4428567          0.9686256
## 182 0.9640689  0.4671487      0.4374430           0.4401458          0.9657221
## 183 0.9577605  0.4671487      0.4320456           0.4347484          0.9599529
## 184 0.9566664  0.4671487      0.4311447           0.4338475          0.9589914
## 185 0.9490062  0.4671487      0.4248382           0.4275411          0.9522417
## 186 0.9456207  0.4671487      0.4221436           0.4248464          0.9493571
## 187 0.9401758  0.4671487      0.4176552           0.4203580          0.9445494
## 188 0.9380748  0.4671487      0.4158534           0.4185562          0.9426264
## 189 0.9357598  0.4671487      0.4131425           0.4149525          0.9405562
## 190 0.9257954  0.4671487      0.4050503           0.4068603          0.9318835
## 191 0.9097919  0.4671487      0.3924699           0.3942799          0.9184220
## 192 0.8998980  0.4671487      0.3843534           0.3861634          0.9097304
## 193 0.8870102  0.4671487      0.3744432           0.3762532          0.8991158
## 194 0.8712119  0.4671487      0.3627473           0.3645573          0.8865781
## 195 0.8530594  0.4671487      0.3501508           0.3519608          0.8731165
## 196 0.8177707  0.4671487      0.3249490           0.3258580          0.8469467
## 197 0.7653048  0.4671487      0.2916313           0.2925404          0.8113132
## 198 0.7112992  0.4671487      0.2601233           0.2610324          0.7775839
## 199 0.6448806  0.4671487      0.2241187           0.2250278          0.7390281
## 200 0.5071381  0.4671487      0.1601774           0.1610865          0.6705703
##      Accuracy     Kappa         J       Dist
## 1   0.5328264 0.1163930 0.1233333 0.87666667
## 2   0.6868354 0.3960236 0.4121447 0.58596856
## 3   0.7525380 0.5187459 0.5354216 0.46269898
## 4   0.8083465 0.6246167 0.6401673 0.35796411
## 5   0.8353501 0.6763265 0.6907888 0.30734550
## 6   0.8605435 0.7249754 0.7380769 0.26008376
## 7   0.8830016 0.7685669 0.7802238 0.21796186
## 8   0.8991696 0.8001131 0.8105628 0.18762287
## 9   0.9099969 0.8213192 0.8308735 0.16733908
## 10  0.9171800 0.8354267 0.8443481 0.15386451
## 11  0.9297929 0.8602620 0.8680204 0.13023673
## 12  0.9387939 0.8780445 0.8849413 0.11331583
## 13  0.9460096 0.8923081 0.8984442 0.09981300
## 14  0.9469105 0.8940945 0.9001391 0.09815331
## 15  0.9523160 0.9048203 0.9102803 0.08801207
## 16  0.9550026 0.9101509 0.9153086 0.08298382
## 17  0.9604082 0.9208899 0.9254498 0.07297863
## 18  0.9631028 0.9262458 0.9305063 0.06792213
## 19  0.9640037 0.9280405 0.9322012 0.06622722
## 20  0.9648966 0.9298239 0.9338679 0.06456055
## 21  0.9657895 0.9315982 0.9355346 0.06289388
## 22  0.9684922 0.9369700 0.9406193 0.05780914
## 23  0.9693931 0.9387646 0.9423142 0.05611422
## 24  0.9729967 0.9459554 0.9490939 0.04933456
## 25  0.9738976 0.9477541 0.9507888 0.04779563
## 26  0.9766085 0.9531755 0.9558735 0.04307186
## 27  0.9766085 0.9531755 0.9558735 0.04307186
## 28  0.9775013 0.9549544 0.9575402 0.04140520
```

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## 29  0.9784022 0.9567531 0.9592351 0.03971028
## 30  0.9793031 0.9585437 0.9609300 0.03801537
## 31  0.9802040 0.9603383 0.9626249 0.03632045
## 32  0.9820060 0.9639423 0.9659865 0.03295887
## 33  0.9820060 0.9639423 0.9659865 0.03295887
## 34  0.9820060 0.9639423 0.9659865 0.03295887
## 35  0.9829069 0.9657451 0.9676814 0.03126395
## 36  0.9829069 0.9657451 0.9676814 0.03126395
## 37  0.9837997 0.9675331 0.9693481 0.02959729
## 38  0.9837997 0.9675331 0.9693481 0.02959729
## 39  0.9837997 0.9675331 0.9693481 0.02959729
## 40  0.9847006 0.9693318 0.9710430 0.02790237
## 41  0.9847006 0.9693318 0.9710430 0.02790237
## 42  0.9847006 0.9693318 0.9710430 0.02790237
## 43  0.9847006 0.9693318 0.9710430 0.02790237
## 44  0.9856015 0.9711347 0.9727379 0.02620746
## 45  0.9865024 0.9729375 0.9744329 0.02451254
## 46  0.9865024 0.9729375 0.9744329 0.02451254
## 47  0.9874033 0.9747444 0.9761278 0.02281763
## 48  0.9874033 0.9747444 0.9761278 0.02281763
## 49  0.9874033 0.9747444 0.9761278 0.02281763
## 50  0.9874033 0.9747444 0.9761278 0.02281763
## 51  0.9874033 0.9747444 0.9761278 0.02281763
## 52  0.9865024 0.9729334 0.9742047 0.02316914
## 53  0.9874033 0.9747321 0.9758996 0.02163021
## 54  0.9883042 0.9765390 0.9775945 0.01993529
## 55  0.9883042 0.9765390 0.9775945 0.01993529
## 56  0.9883042 0.9765390 0.9775945 0.01993529
## 57  0.9883042 0.9765390 0.9775945 0.01993529
## 58  0.9883042 0.9765390 0.9775945 0.01993529
## 59  0.9883042 0.9765390 0.9775945 0.01993529
## 60  0.9883042 0.9765390 0.9775945 0.01993529
## 61  0.9883042 0.9765390 0.9775945 0.01993529
## 62  0.9883042 0.9765390 0.9775945 0.01993529
## 63  0.9883042 0.9765390 0.9775945 0.01993529
## 64  0.9883042 0.9765390 0.9775945 0.01993529
## 65  0.9883042 0.9765390 0.9775945 0.01993529
## 66  0.9883042 0.9765390 0.9775945 0.01993529
## 67  0.9892051 0.9783459 0.9792894 0.01929498
## 68  0.9892051 0.9783459 0.9792894 0.01929498
## 69  0.9892051 0.9783459 0.9792894 0.01929498
## 70  0.9900980 0.9801339 0.9809561 0.01762832
## 71  0.9909989 0.9819367 0.9826510 0.01629438
## 72  0.9918917 0.9837293 0.9843177 0.01462771
## 73  0.9918917 0.9837293 0.9843177 0.01462771
## 74  0.9918917 0.9837293 0.9843177 0.01462771
## 75  0.9918917 0.9837293 0.9843177 0.01462771
## 76  0.9918917 0.9837293 0.9843177 0.01462771
## 77  0.9918917 0.9837293 0.9843177 0.01462771
## 78  0.9918917 0.9837293 0.9843177 0.01462771
## 79  0.9918917 0.9837293 0.9843177 0.01462771
## 80  0.9918917 0.9837293 0.9843177 0.01462771
## 81  0.9918917 0.9837293 0.9843177 0.01462771
## 82  0.9918917 0.9837293 0.9843177 0.01462771
```

```
## 83  0.9918917 0.9837293 0.9843177 0.01462771
## 84  0.9918917 0.9837293 0.9843177 0.01462771
## 85  0.9918917 0.9837293 0.9843177 0.01462771
## 86  0.9918917 0.9837293 0.9843177 0.01462771
## 87  0.9927926 0.9855363 0.9860126 0.01293279
## 88  0.9927926 0.9855363 0.9860126 0.01293279
## 89  0.9927926 0.9855363 0.9860126 0.01293279
## 90  0.9927926 0.9855363 0.9860126 0.01293279
## 91  0.9927926 0.9855363 0.9860126 0.01293279
## 92  0.9927926 0.9855363 0.9860126 0.01293279
## 93  0.9927926 0.9855363 0.9860126 0.01293279
## 94  0.9927926 0.9855363 0.9860126 0.01293279
## 95  0.9927926 0.9855363 0.9860126 0.01293279
## 96  0.9927926 0.9855363 0.9860126 0.01293279
## 97  0.9927926 0.9855363 0.9860126 0.01293279
## 98  0.9927926 0.9855363 0.9860126 0.01293279
## 99  0.9918917 0.9837252 0.9840895 0.01344029
## 100 0.9927926 0.9855321 0.9857844 0.01174538
## 101 0.9927926 0.9855321 0.9857844 0.01174538
## 102 0.9927926 0.9855321 0.9857844 0.01174538
## 103 0.9927926 0.9855321 0.9857844 0.01174538
## 104 0.9927926 0.9855321 0.9857844 0.01174538
## 105 0.9927926 0.9855321 0.9857844 0.01174538
## 106 0.9927926 0.9855321 0.9857844 0.01174538
## 107 0.9927926 0.9855321 0.9857844 0.01174538
## 108 0.9927926 0.9855321 0.9857844 0.01174538
## 109 0.9927926 0.9855321 0.9857844 0.01174538
## 110 0.9927926 0.9855321 0.9857844 0.01174538
## 111 0.9927926 0.9855321 0.9857844 0.01174538
## 112 0.9927926 0.9855321 0.9857844 0.01174538
## 113 0.9927926 0.9855321 0.9857844 0.01174538
## 114 0.9927926 0.9855321 0.9857844 0.01174538
## 115 0.9927926 0.9855321 0.9857844 0.01174538
## 116 0.9927926 0.9855321 0.9857844 0.01174538
## 117 0.9936935 0.9873391 0.9874794 0.01110507
## 118 0.9936935 0.9873391 0.9874794 0.01110507
## 119 0.9936935 0.9873391 0.9874794 0.01110507
## 120 0.9936935 0.9873391 0.9874794 0.01110507
## 121 0.9936935 0.9873391 0.9874794 0.01110507
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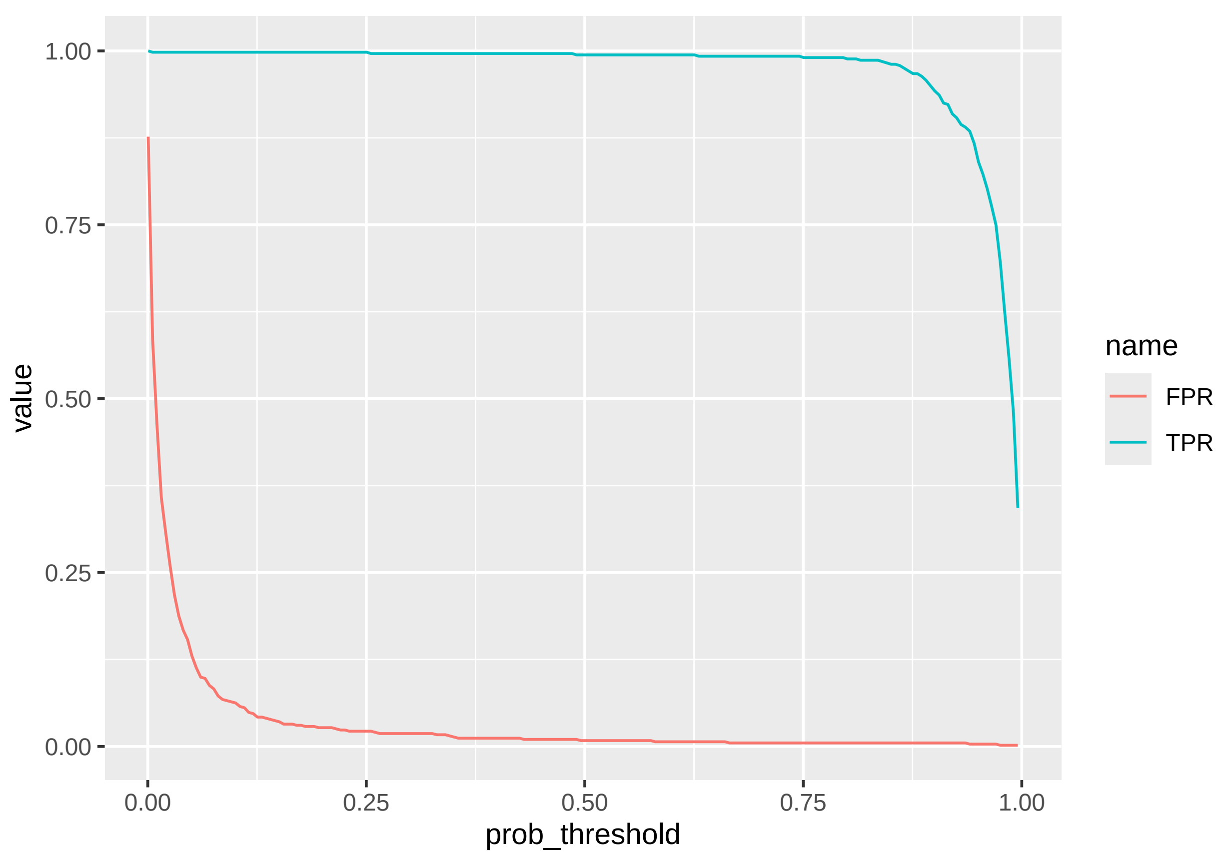
## 124 0.9936935 0.9873391 0.9874794 0.01110507
## 125 0.9936935 0.9873391 0.9874794 0.01110507
## 126 0.9936935 0.9873391 0.9874794 0.01110507
## 127 0.9928007 0.9855419 0.9855563 0.01302814
## 128 0.9928007 0.9855419 0.9855563 0.01302814
## 129 0.9928007 0.9855419 0.9855563 0.01302814
## 130 0.9928007 0.9855419 0.9855563 0.01302814
## 131 0.9928007 0.9855419 0.9855563 0.01302814
## 132 0.9928007 0.9855419 0.9855563 0.01302814
## 133 0.9928007 0.9855419 0.9855563 0.01302814
## 134 0.9937016 0.9873447 0.9872512 0.01169420
## 135 0.9937016 0.9873447 0.9872512 0.01169420
## 136 0.9937016 0.9873447 0.9872512 0.01169420
```

```
## 137 0.9937016 0.9873447 0.9872512 0.01169420
## 138 0.9937016 0.9873447 0.9872512 0.01169420
## 139 0.9937016 0.9873447 0.9872512 0.01169420
## 140 0.9937016 0.9873447 0.9872512 0.01169420
## 141 0.9937016 0.9873447 0.9872512 0.01169420
## 142 0.9937016 0.9873447 0.9872512 0.01169420
## 143 0.9937016 0.9873447 0.9872512 0.01169420
## 144 0.9937016 0.9873447 0.9872512 0.01169420
## 145 0.9937016 0.9873447 0.9872512 0.01169420
## 146 0.9937016 0.9873447 0.9872512 0.01169420
## 147 0.9937016 0.9873447 0.9872512 0.01169420
## 148 0.9937016 0.9873447 0.9872512 0.01169420
## 149 0.9937016 0.9873447 0.9872512 0.01169420
## 150 0.9937016 0.9873447 0.9872512 0.01169420
## 151 0.9928007 0.9855336 0.9853281 0.01361728
## 152 0.9928007 0.9855336 0.9853281 0.01361728
## 153 0.9928007 0.9855336 0.9853281 0.01361728
## 154 0.9928007 0.9855336 0.9853281 0.01361728
## 155 0.9928007 0.9855336 0.9853281 0.01361728
## 156 0.9928007 0.9855336 0.9853281 0.01361728
## 157 0.9928007 0.9855336 0.9853281 0.01361728
## 158 0.9928007 0.9855336 0.9853281 0.01361728
## 159 0.9928007 0.9855336 0.9853281 0.01361728
## 160 0.9928007 0.9855336 0.9853281 0.01361728
## 161 0.9918998 0.9837226 0.9834050 0.01554036
## 162 0.9918998 0.9837226 0.9834050 0.01554036
## 163 0.9918998 0.9837226 0.9834050 0.01554036
## 164 0.9909989 0.9819074 0.9814820 0.01746343
## 165 0.9909989 0.9819074 0.9814820 0.01746343
## 166 0.9909989 0.9819074 0.9814820 0.01746343
## 167 0.9909989 0.9819074 0.9814820 0.01746343
## 168 0.9909989 0.9819074 0.9814820 0.01746343
## 169 0.9900980 0.9800880 0.9795589 0.01938651
## 170 0.9891971 0.9782728 0.9776358 0.02130959
## 171 0.9882962 0.9764618 0.9757127 0.02323266
## 172 0.9882962 0.9764618 0.9757127 0.02323266
## 173 0.9873953 0.9746507 0.9737897 0.02515574
## 174 0.9855935 0.9710203 0.9699435 0.02900189
## 175 0.9837917 0.9673857 0.9660973 0.03284805
## 176 0.9819899 0.9637512 0.9622512 0.03641079
## 177 0.9819899 0.9637512 0.9622512 0.03641079
## 178 0.9801881 0.9601041 0.9584050 0.04025694
## 179 0.9774854 0.9546460 0.9526358 0.04602617
## 180 0.9738898 0.9473824 0.9449435 0.05256046
## 181 0.9703023 0.9401188 0.9372512 0.05980766
## 182 0.9675914 0.9346330 0.9314443 0.06455069
## 183 0.9621940 0.9236800 0.9199058 0.07605288
## 184 0.9612931 0.9218439 0.9179827 0.07797595
## 185 0.9549867 0.9089919 0.9044835 0.09119479
## 186 0.9522920 0.9034788 0.8987142 0.09696402
## 187 0.9478036 0.8943296 0.8890989 0.10657940
## 188 0.9460018 0.8906742 0.8852527 0.11042556
## 189 0.9441838 0.8869459 0.8811124 0.11588529
## 190 0.9360916 0.8704200 0.8637670 0.13313047
```

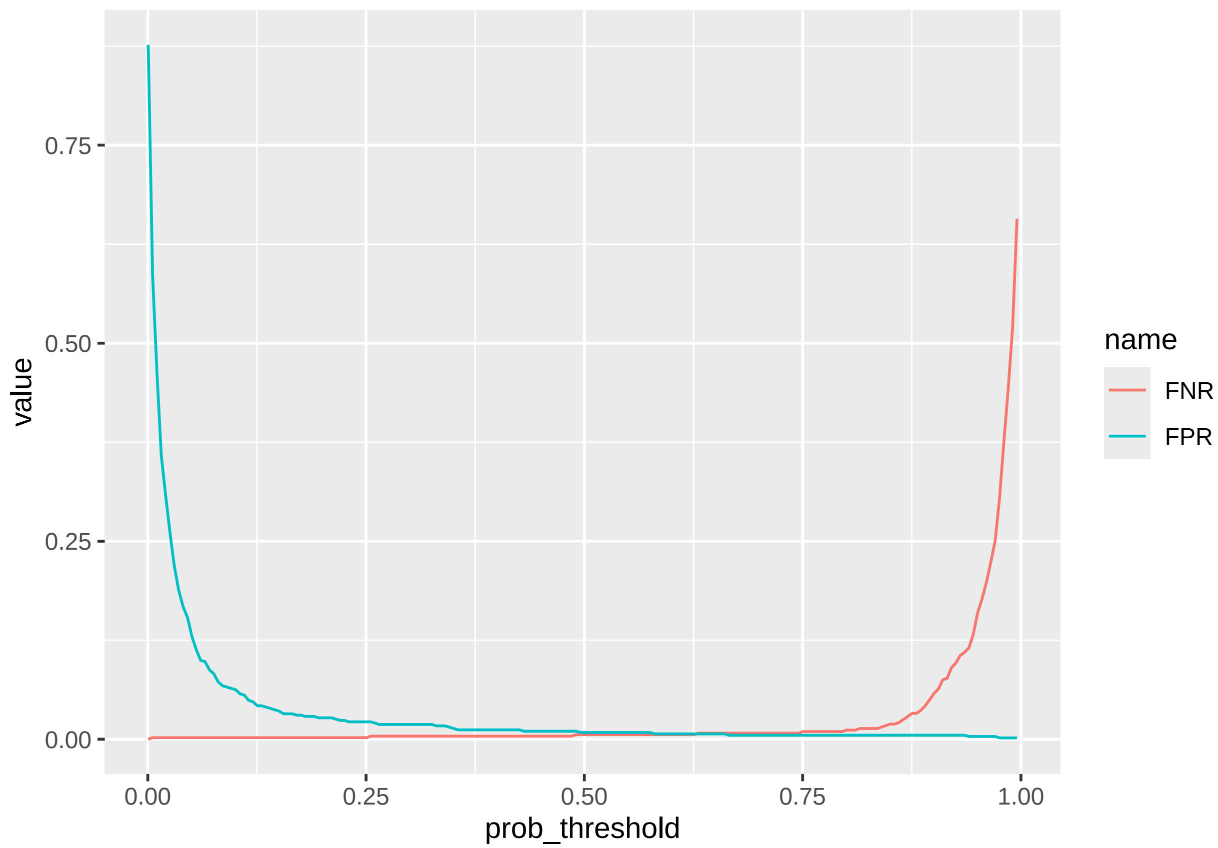
```
## 191 0.9235112 0.8446352 0.8368440 0.16003005
## 192 0.9153947 0.8280763 0.8194608 0.17734533
## 193 0.9054845 0.8077117 0.7982316 0.19853768
## 194 0.8937886 0.7835623 0.7731562 0.22358927
## 195 0.8811921 0.7574182 0.7462331 0.25051235
## 196 0.8568912 0.7068214 0.6938933 0.30446056
## 197 0.8235735 0.6369720 0.6226264 0.37571941
## 198 0.7920655 0.5702983 0.5551678 0.44317054
## 199 0.7560609 0.4935467 0.4780562 0.52027599
## 200 0.6921196 0.3552551 0.3411407 0.65718420
```

```r
set.seed(702)
pldf = gbmfit_res %>%
  mutate(TPR = Sensitivity, FPR = 1 - Specificity, FNR = 1 - Sensitivity) %>%
  dplyr::select(-c(n.trees, interaction.depth, shrinkage, n.minobsinnode)) %>%
  pivot_longer(-prob_threshold)
```

```r
set.seed(702)
ggplot(aes(x=prob_threshold, y=value, color = name),
       data = pldf %>% filter(name %in% c('TPR', 'FPR'))) +
  geom_line()
```

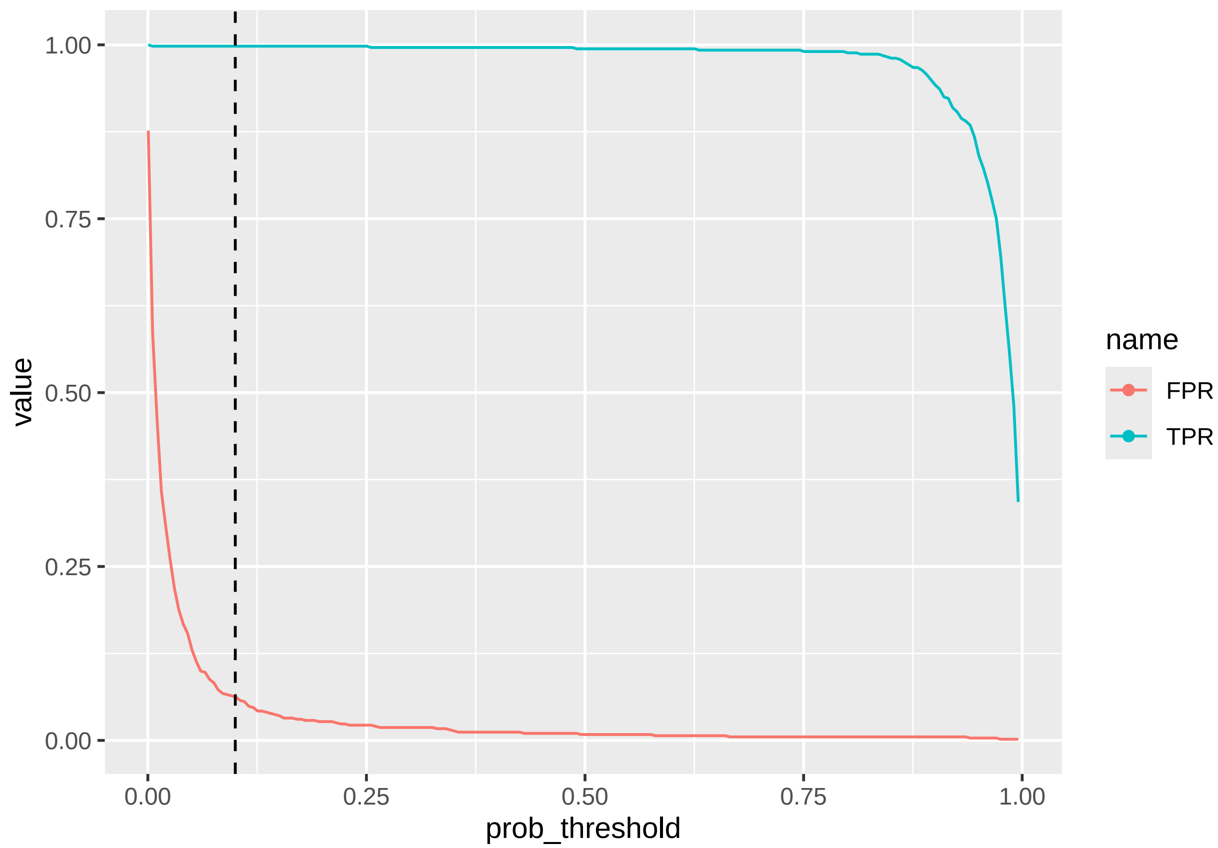



```r
ggplot(aes(x=prob_threshold, y= value, color = name),
       data = pldf %>% filter(name %in% c('FNR', 'FPR'))) +
  geom_line()
```

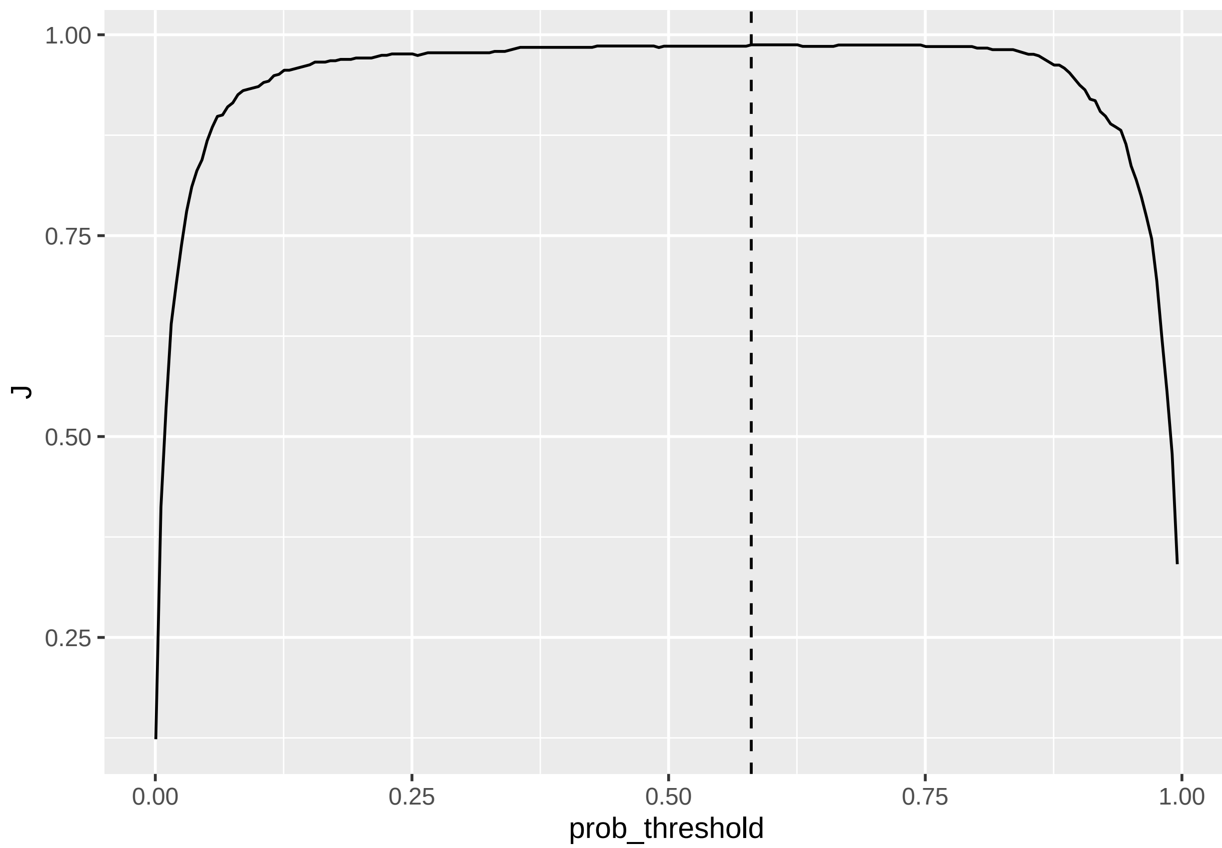



```
set.seed(702)
thres = 0.1

tp = gbmfit_res %>%
  dplyr::filter(prob_threshold==thres) %>%
  dplyr::select(prob_threshold, Sensitivity, Specificity) %>%
  mutate(TPR = Sensitivity, FPR = 1-Specificity)
```

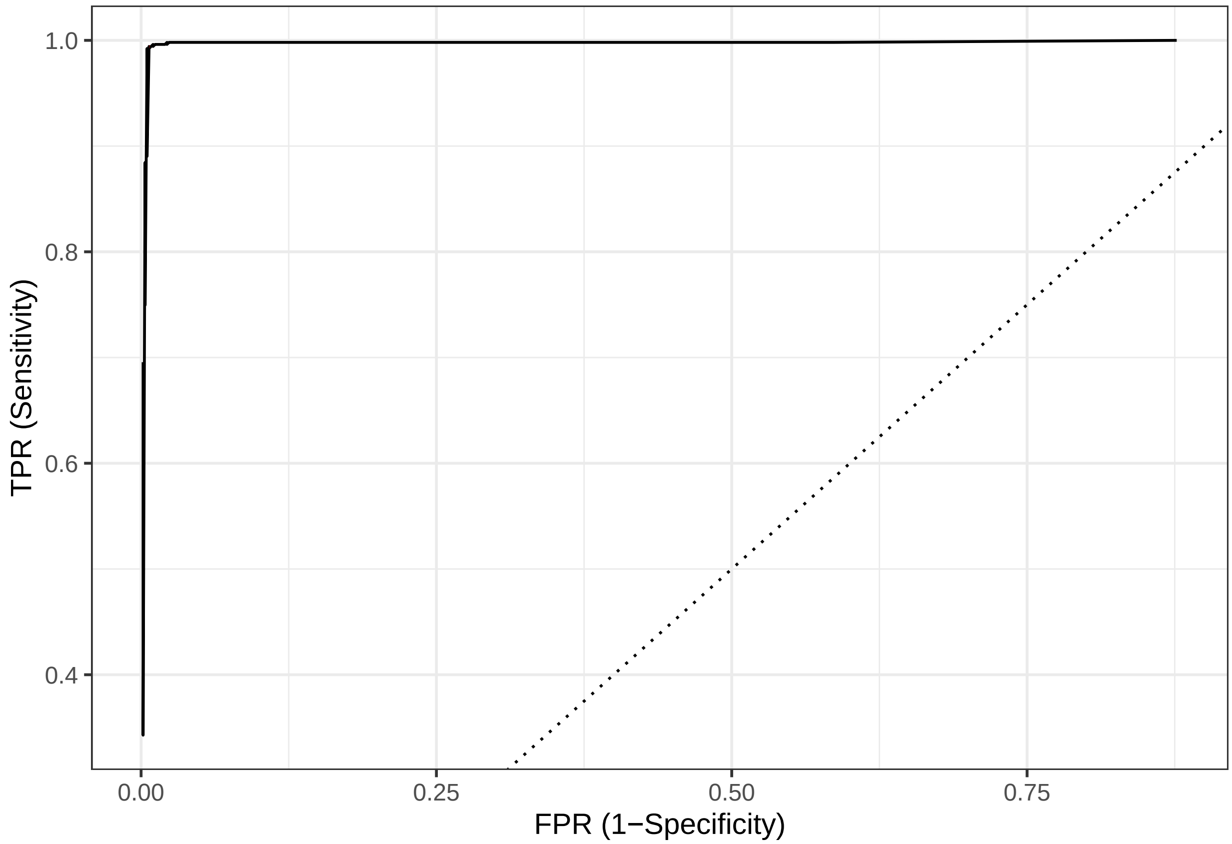
```
set.seed(702)
ggplot(aes(x=prob_threshold, y=value, color = name),
       data = pldf %>% filter(name %in% c('TPR','FPR'))) +
  geom_line() +
  geom_vline(xintercept = thres, lty = 2) +
  geom_point(aes(x=prob_threshold, y=TPR, color = NULL), data = tp) +
  geom_point(aes(x=prob_threshold, y = FPR, color = NULL), data = tp)
```



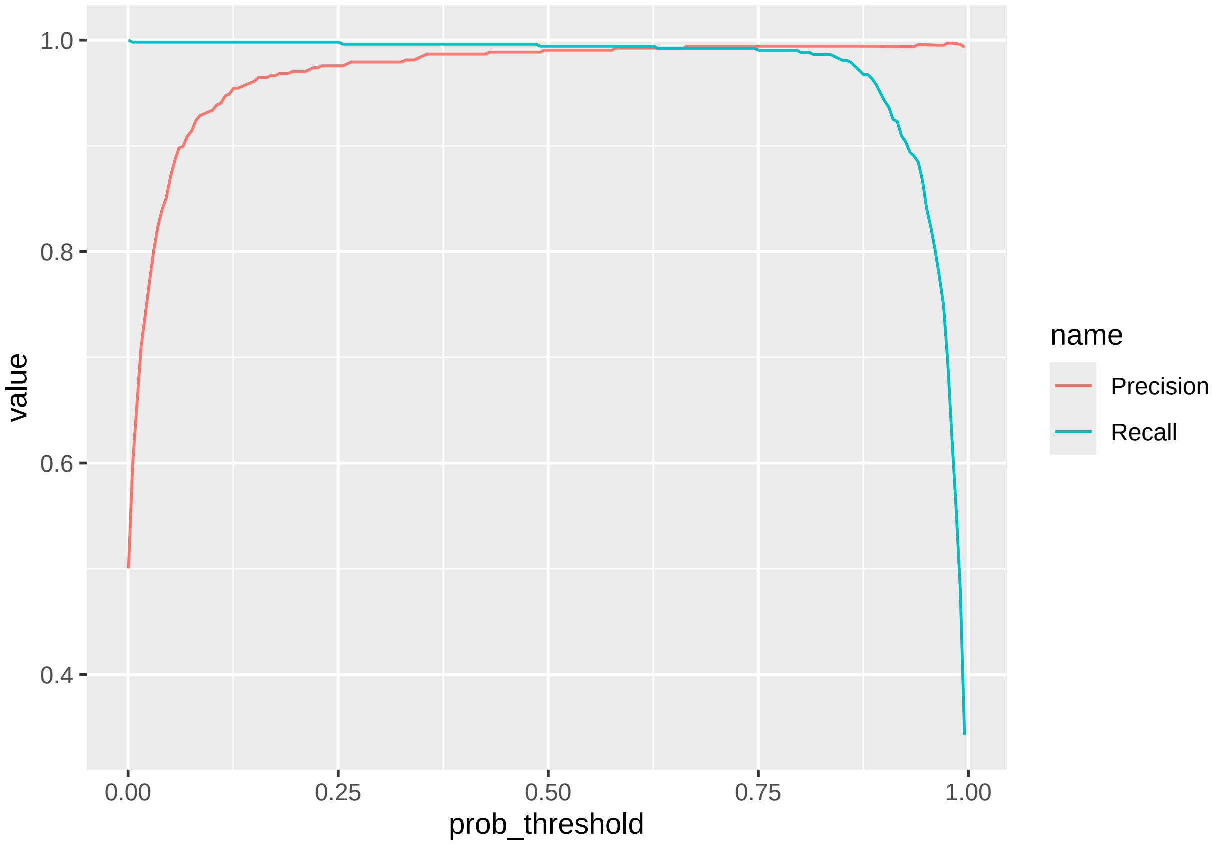

```
set.seed(702)
optim_J = gbmfit_res[which.max(gbmfit_res$J),]

ggplot(aes(x=prob_threshold, y=J),
       data = gbmfit_res) +
  geom_line() +
  geom_vline(aes(xintercept = optim_J$prob_threshold), lty = 2)
```



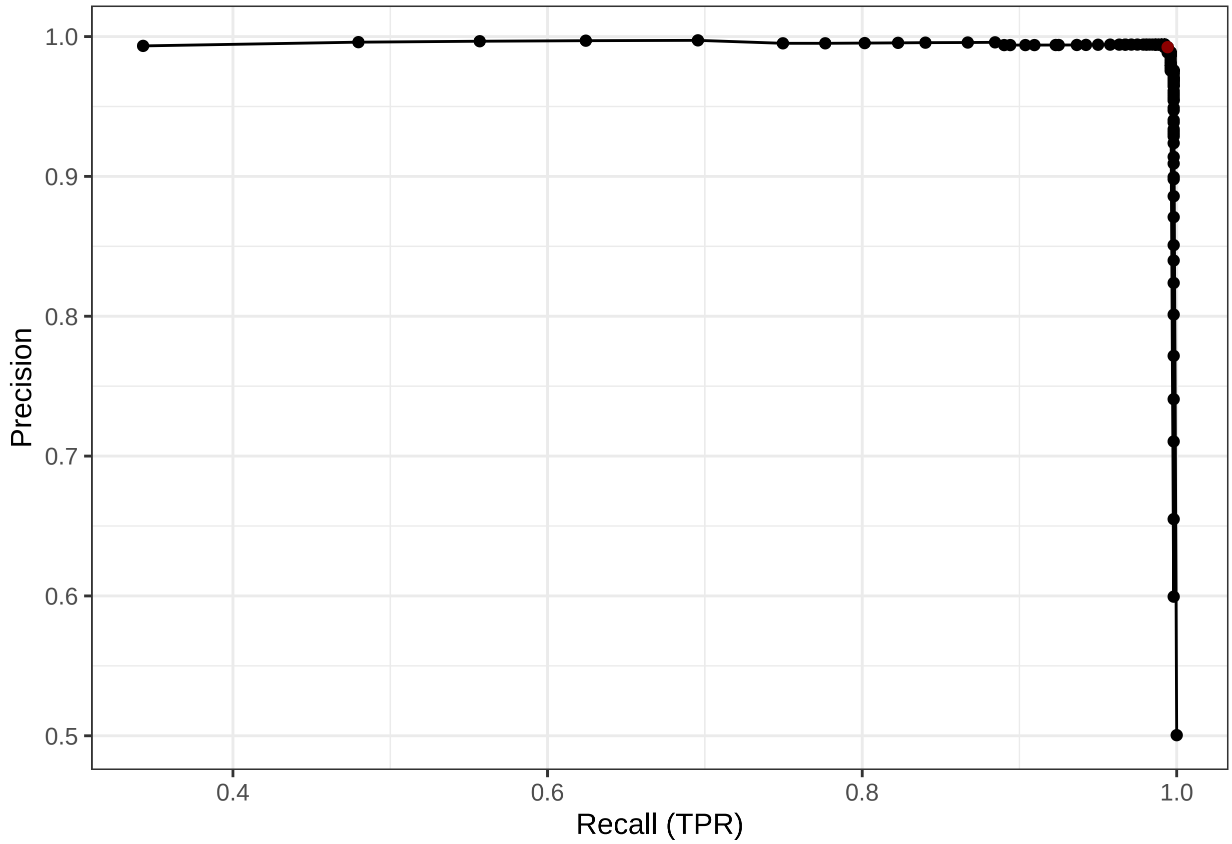

```
ggplot(aes(x=1 - Specificity, y = Sensitivity), data = gbmfit_res) +
  geom_line() +
  ylab('TPR (Sensitivity)') +
  xlab('FPR (1-Specificity)') +
  geom_abline(intercept = 0, slope = 1, linetype = 'dotted') +
  geom_segment(aes(x = 1-Specificity, xend=1-Specificity, y = Sensitivity, yend = Sensitivity), color =
```




```r
set.seed(702)
ggplot(aes(x=prob_threshold, y=value, color = name),
       data=pldf %>% filter(name %in% c('Precision','Recall')))+
  geom_line()
```



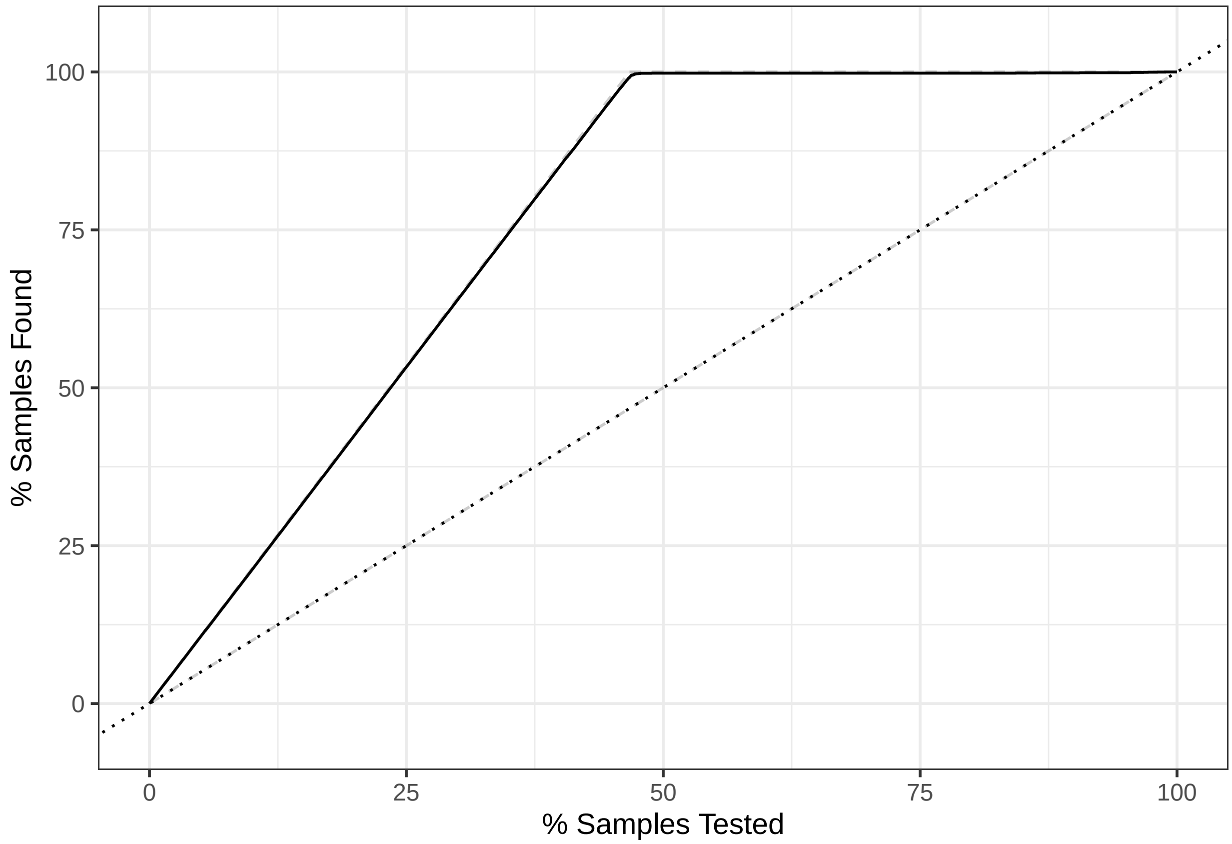

```
ggplot(aes(x=Recall, y = Precision), data = gbmfit_res) +
  geom_point() +
  geom_line() +
  ylab('Precision') +
  xlab('Recall (TPR)') +
  geom_point(aes(x=Recall, y=Precision), color = 'darkred', data = optim_J) +
  theme_bw()
```



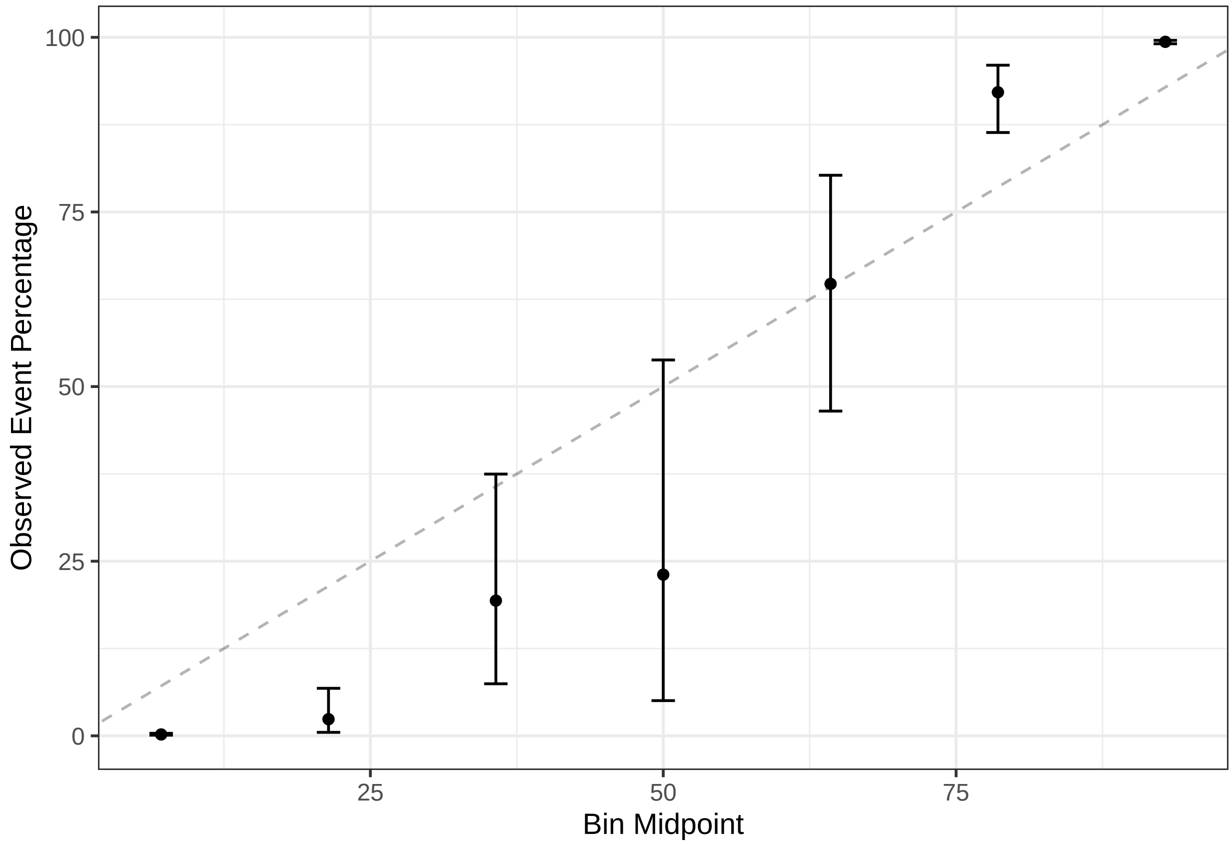

```r
set.seed(702)
best_pars = gbmfit$bestTune
best_preds = gbmfit$pred %>% filter(n.trees==best_pars$n.trees, interaction.depth==best_pars$interactio

gbm_lift = caret::lift(obs~Yes, data = best_preds)
```

```r
set.seed(702)
ggplot(gbm_lift) +
  geom_abline(slope = 1, linetype = "dotted") +
  xlim(c(0,100)) +
  theme_bw()
```

```
## Scale for x is already present.
## Adding another scale for x, which will replace the existing scale.
```




```
set.seed(702)
gbm_cal = caret:: calibration(obs~Yes, data = best_preds, cuts = 7)
ggplot(gbm_cal) + theme_bw()
```




```r
set.seed(702)
test_probs = predict(gbmfit, newdata = unique_customers_test, type='prob')

test_preds <- factor(ifelse(test_probs[, "Yes"] > optim_J$prob_threshold, "Yes", "No"))
test_conf_matrix = predict(gbmfit, newdata = unique_customers_test)

test_conf_matrix
```

```
##   [1] Yes Yes No  Yes No  Yes Yes No  No  No  No  Yes No  No  Yes Yes Yes Yes
##  [19] No  Yes Yes Yes No  Yes No  No  No  No  No  Yes No  Yes No  Yes No  No
##  [37] Yes No  No  Yes Yes Yes Yes No  Yes Yes No  Yes No  Yes No  No  Yes Yes
##  [55] Yes Yes Yes Yes No  No  No  No  No  No  No  No  Yes Yes No  Yes Yes No
##  [73] No  No  Yes Yes No  No  No  No  No  No  No  No  No  Yes Yes Yes Yes Yes
##  [91] No  Yes Yes No  No  Yes Yes No  No  No  Yes No  No  No  Yes No  Yes Yes
## [109] Yes No  Yes Yes Yes Yes No  No  Yes No  Yes No  Yes Yes No  No  No  Yes
## [127] Yes No  Yes No  No  No  No  No  No  Yes Yes Yes No  No  No  No  Yes No
## [145] Yes Yes Yes No  No  No  No  No  No  No  No  No  No  No  Yes No  No  No
## [163] Yes No  Yes Yes Yes Yes Yes No  Yes Yes No  No  No  No  Yes Yes Yes Yes
## [181] Yes No  Yes No  No  Yes Yes No  No  Yes No  No  Yes No  No  No  Yes Yes
## [199] Yes No  Yes Yes Yes Yes Yes Yes Yes No  Yes No  Yes Yes Yes No  Yes No
## [217] Yes Yes No  No  No  Yes Yes No  Yes No  Yes Yes No  No  No  Yes Yes Yes
## [235] No  No  Yes No  No  No  No  Yes No  Yes No  No  Yes Yes No  Yes Yes No
## [253] Yes No  Yes No  No  Yes No  No  No  No  No  No  Yes No  Yes Yes Yes Yes
## [271] No  Yes No  Yes Yes No  Yes
## Levels: Yes No
```

```r
print(confusionMatrix(test_preds, unique_customers_test$PurchaseStatus))
```

```
## Warning in confusionMatrix.default(test_preds,
## unique_customers_test$PurchaseStatus): Levels are not in the same order for
## reference and data. Refactoring data to match.

## Confusion Matrix and Statistics
##
##           Reference
## Prediction Yes  No
##        Yes 119  11
##        No   10 137
##
##                Accuracy : 0.9242
##                  95% CI : (0.8864, 0.9525)
##     No Information Rate : 0.5343
##     P-Value [Acc > NIR] : <2e-16
##
##                   Kappa : 0.8477
##
##  Mcnemar's Test P-Value : 1
##
##             Sensitivity : 0.9225
##             Specificity : 0.9257
##          Pos Pred Value : 0.9154
##          Neg Pred Value : 0.9320
##              Prevalence : 0.4657
##          Detection Rate : 0.4296
##    Detection Prevalence : 0.4693
##       Balanced Accuracy : 0.9241
##
##        'Positive' Class : Yes
##
```

```r
get_metrics = function(threshold, test_probs, true_class,
                       pos_label, neg_label){
  pc = factor(ifelse(test_probs[pos_label]>threshold, pos_label, neg_label), levels=c(pos_label, neg_la
  test_set = data.frame(obs= true_class, pred=pc, test_probs)
  my_summary(test_set, lev= c(pos_label, neg_label))
}

get_metrics(optim_J$prob_threshold, test_probs, unique_customers_test$PurchaseStatus, 'Yes', 'No')
```

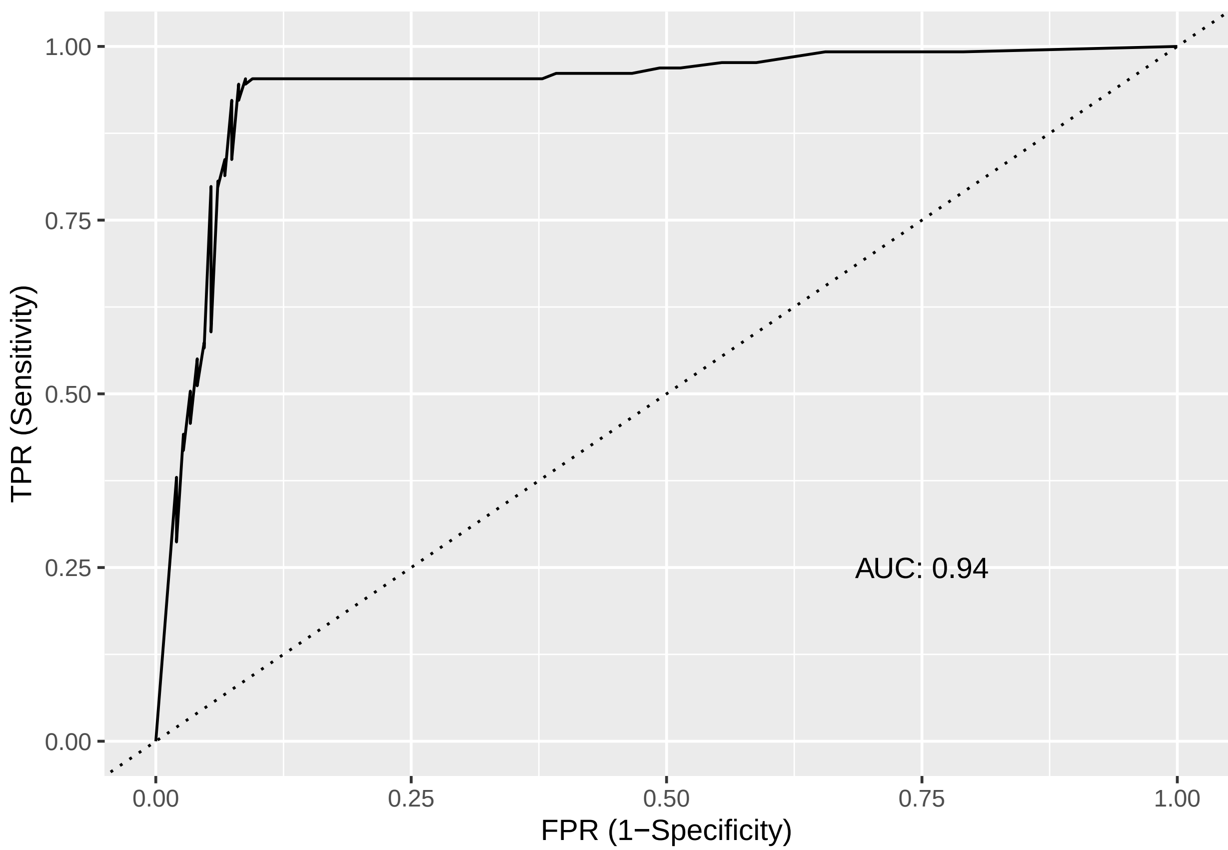
```
##   Accuracy      Kappa    AUC_ROC        TPR        FPR    logLoss
## 0.92418773 0.84773447 0.93698931 0.92248062 0.07432432 0.35117326
```

```r
thr_seq = seq(0,1, length.out = 500)
metrics = lapply(thr_seq, function(x) get_metrics(x, test_probs, unique_customers_test$PurchaseStatus,
metrics_df = data.frame(do.call(rbind, metrics))
varImp(gbmfit)
```

```
## gbm variable importance
##
##                                          Overall
## TimeSpentOnWebsite                        100.00
## Age                                        68.77
```

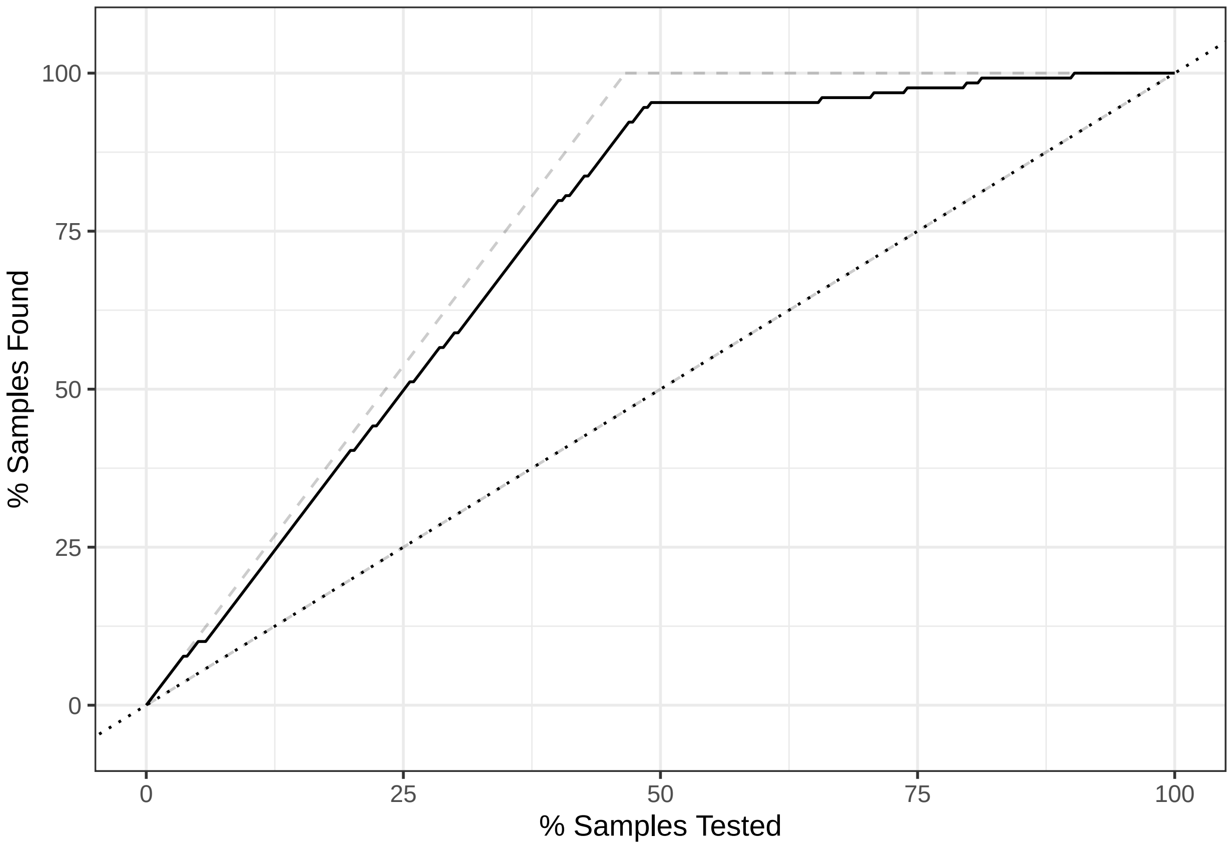
```
## AnnualIncome                                 67.39
## NumberOfPurchases                            53.66
## LoyaltyDiscInteraction                       41.86
## LoyaltyProgram1                              37.57
## DiscountsAvailed                             31.13
## CatDiscountsAvailedHigh Discounts Availed   11.45
## Gender1                                       0.00
```

```
ggplot(aes(x=FPR, y = TPR), data = metrics_df) +
  geom_line() +
  ylab('TPR (Sensitivity)') +
  xlab('FPR (1-Specificity)') +
  geom_abline(intercept = 0, slope = 1, linetype = 'dotted') +
  annotate('text', x=0.75, y=0.25, label = paste('AUC:', round(metrics_df$AUC_ROC[1], 2)))
```

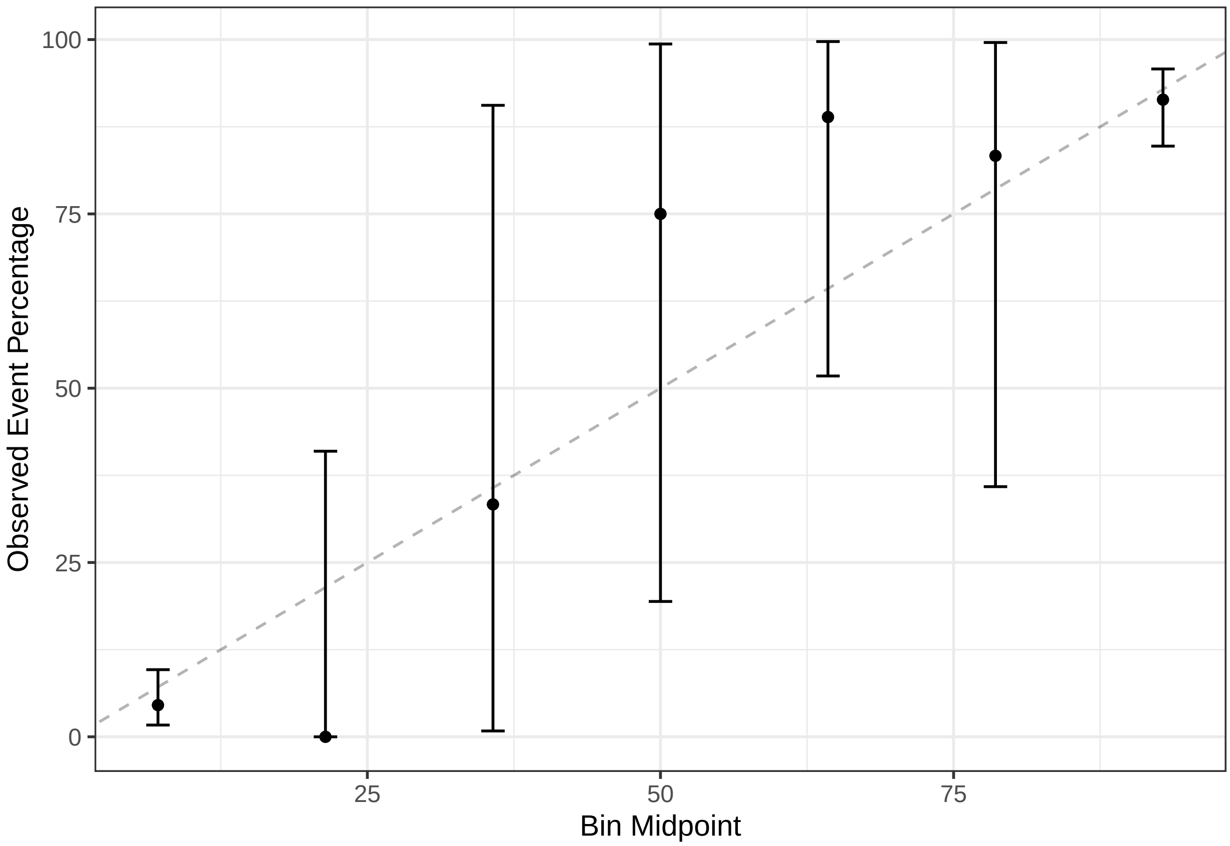



```
gbm_oos_lift = caret::lift(unique_customers_test$PurchaseStatus~test_probs[,1])

ggplot(gbm_oos_lift) +
  geom_abline(slope = 1, linetype ='dotted') +
  xlim(c(0,100)) +
  theme_bw()
```

```
## Scale for x is already present.
## Adding another scale for x, which will replace the existing scale.
```




```
gbm_cal = caret::calibration(unique_customers_test$PurchaseStatus~test_probs[,1], data = best_preds, cu

ggplot(gbm_cal) + theme_bw()
```



100
75
50
25
0
Observed Event Percentage
25
50
75
Bin Midpoint