title: “Lab 9” author: “Asher KAtz” output: pdf_document —

In this next first part of this lab, we will be joining three datasets in an effort to make a design matrix that predicts if a bill will be paid on time. Clean up and load up the three files. Then I’ll rename a few features and then we can examine the data frames:

```
rm(list = ls())
pacman::p_load(tidyverse, magrittr, data.table, R.utils)
bills_data = fread("https://github.com/kapelner/QC_MATH_342W_Spring_2021/raw/master/labs/bills_dataset/b
payments = fread("https://github.com/kapelner/QC_MATH_342W_Spring_2021/raw/master/labs/bills_dataset/pay
discounts = fread("https://github.com/kapelner/QC_MATH_342W_Spring_2021/raw/master/labs/bills_dataset/di
setnames(bills_data, "amount", "tot_amount")
setnames(payments, "amount", "paid_amount")
head(bills_data)
```

```
##          id   due_date invoice_date tot_amount customer_id discount_id
## 1: 15163811 2017-02-12   2017-01-13   99490.77    14290629     5693147
## 2: 17244832 2016-03-22   2016-02-21   99475.73    14663516     5693147
## 3: 16072776 2016-08-31   2016-07-17   99477.03    14569622     7302585
## 4: 15446684 2017-05-29   2017-05-29   99478.60    14488427     5693147
## 5: 16257142 2017-06-09   2017-05-10   99678.17    14497172     5693147
## 6: 17244880 2017-01-24   2017-01-24   99475.04    14663516     5693147
```

```
head(payments)
```

```
##          id paid_amount transaction_date  bill_id
## 1: 15272980    99165.60       2017-01-16 16571185
## 2: 15246935    99148.12       2017-01-03 16660000
## 3: 16596393    99158.06       2017-06-19 16985407
## 4: 16596651    99175.03       2017-06-19 17062491
## 5: 16687702    99148.20       2017-02-15 17184583
## 6: 16593510    99153.94       2017-06-11 16686215
```

```
head(discounts)
```

```
##         id num_days pct_off days_until_discount
## 1: 5000000       20      NA                  NA
## 2: 5693147       NA       2                  NA
## 3: 6098612       20      NA                  NA
## 4: 6386294      120      NA                  NA
## 5: 6609438       NA       1                   7
## 6: 6791759       31       1                  NA
```

The unit we care about is the bill. The y metric we care about will be “paid in full” which is 1 if the company paid their total amount (we will generate this y metric later).

Since this is the response, we would like to construct the very best design matrix in order to predict y.

I will create the basic steps for you guys. First, join the three datasets in an intelligent way. You will need to examine the datasets beforehand.

```
bills_with_payments = merge(bills_data, payments, all.x = TRUE, by.x = "id", by.y = "bill_id")
bills_with_payments[, id.y := NULL]

discounts[,discount_num_days := factor(num_days)]
discounts[,discount_pct_off := factor(pct_off)]
discounts[,discount_days_until_discount := factor(days_until_discount)]
discounts[is.na(discount_num_days), discount_num_days := "missing"]
discounts[is.na(discount_pct_off), discount_pct_off := "missing"]
discounts[is.na(discount_days_until_discount), discount_days_until_discount := "missing"]

bills_with_payments_with_discounts = merge(bills_with_payments, discounts, all.x = TRUE, by.x = "discou
colnames(bills_with_payments_with_discounts)
```

```
##  [1] "discount_id"                "id"
##  [3] "due_date"                   "invoice_date"
##  [5] "tot_amount"                 "customer_id"
##  [7] "paid_amount"                "transaction_date"
##  [9] "num_days"                   "pct_off"
## [11] "days_until_discount"        "discount_num_days"
## [13] "discount_pct_off"           "discount_days_until_discount"
```

```
setorder(bills_with_payments_with_discounts, id)
```

Now create the binary response metric `paid_in_full` as the last column and create the beginnings of a design matrix `bills_data`. Ensure the unit / observation is bill i.e. each row should be one bill!

```
#TO-DO


bills_with_payments_with_discounts[, total_paid_so_far := sum(paid_amount, na.rm = TRUE), by = id]
#ideally should be cumamalitve sum
bills_with_payments_with_discounts[, paid_bill := total_paid_so_far >= tot_amount, by = id]
bills_data = bills_with_payments_with_discounts[, .(paid_in_full = any(paid_bill)), by = id]
table(bills_data$paid_in_full, useNA = "always")
```

```
##
##  FALSE   TRUE   <NA>
## 199061  27373      0
```

How should you add features from transformations (called "featurization")? What data type(s) should they be? Make some features below if you think of any useful ones. Name the columns appropriately so another data scientist can easily understand what information is in your variables.

```
#TO-DO
pacman::p_load(lubridate)
bills_with_payments_with_discounts[,num_days_to_pay := as.integer(ymd(due_date) - ymd(invoice_date))]

bills_data = bills_with_payments_with_discounts[,.(
  paid_in_full = as.integer(any(paid_bill)),
  customer_id = first(customer_id),
  tot_amount=first(tot_amount),
```

```
  num_days_to_pay = first(num_days_to_pay),
  discount_pct_off = first(discount_pct_off),
  discount_days_until_discount =first(discount_days_until_discount)
), by = id]
bills_data[,discount_pct_off := factor(discount_pct_off, exclude = NULL)]

bills_data[ ,num_previous_bills := 0 : (.N - 1), by = customer_id]

bills_data[, customer_id:= NULL]

bills_data[num_days_to_pay == 0, num_days_to_pay:= 1]
bills_data[, dollars_owed_per_day := tot_amount/ num_days_to_pay]
bills_data[, paid_in_full := factor(paid_in_full)]
bills_data[, id:= NULL]
bills_data
```

```
##         paid_in_full tot_amount num_days_to_pay discount_pct_off
##      1:            0   99480.18              45          missing
##      2:            0   99528.76              30          missing
##      3:            0   99477.35              11          missing
##      4:            0   99479.31               1          missing
##      5:            0   99477.20              30          missing
##     ---
## 226430:            0   99478.67               1                2
## 226431:            0   99688.54              30          missing
## 226432:            0   99484.81               1          missing
## 226433:            0   99572.44              45          missing
## 226434:            0   99475.44              30          missing
##         discount_days_until_discount num_previous_bills dollars_owed_per_day
##      1:                           10                  0             2210.671
##      2:                           10                  0             3317.625
##      3:                           10                  0             9043.396
##      4:                           10                  1            99479.312
##      5:                           10                  2             3315.907
##     ---
## 226430:                      missing                 17            99478.669
## 226431:                      missing                114             3322.951
## 226432:                      missing                314            99484.806
## 226433:                      missing                137             2212.721
## 226434:                      missing                  4             3315.848
```

Now let's do this exercise. Let's retain 25% of our data for test.

```
K = 4
test_indices = sample(1 : nrow(bills_data), round(nrow(bills_data) / K))
train_indices = setdiff(1 : nrow(bills_data), test_indices)
bills_data_test = bills_data[test_indices, ]
Xtest = bills_data_test[,-"paid_in_full"]
ytest = bills_data_test[,paid_in_full]
bills_data_train = bills_data[train_indices, ]
```

Now try to build a classification tree model for `paid_in_full` with the features (use the `Xy` parameter in `YARF`). If you cannot get `YARF` to install, use the package `rpart` (the standard R tree package) instead. You will need to install it and read through some documentation to find the correct syntax.

Warning: this data is highly anonymized and there is likely zero signal! So don't expect to get predictive accuracy. The value of the exercise is in the practice. I think this exercise (with the joining exercise above) may be one of the most useful exercises in the entire semester.

```
#TO-DO
pacman::p_load(rpart, rpart.plot)
# n_sub_train = 10000
# bills_data_train_sub = bills_data_train[sample(1:.N, n_sub_train)]
# bills_data_test_sub = bills_data_test[sample(1:.N, n_sub_train)]
Xtrain = bills_data_train[,-"paid_in_full"]
ytrain = bills_data_train[, paid_in_full]
classification_tree_mod = rpart(ytrain ~ tot_amount + num_days_to_pay + discount_pct_off + discount_days
```

For those of you who installed `YARF`, what are the number of nodes and depth of the tree?

```
#TO-DO
summary(classification_tree_mod)
```

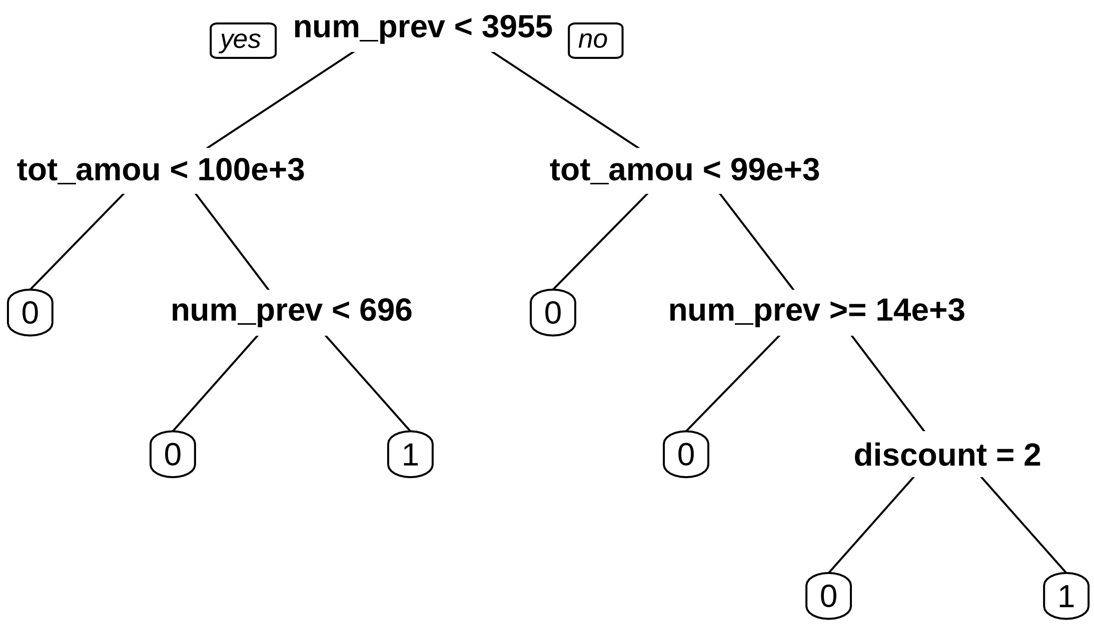
```
## Call:
## rpart(formula = ytrain ~ tot_amount + num_days_to_pay + discount_pct_off +
##     discount_days_until_discount + num_previous_bills + dollars_owed_per_day,
##     data = bills_data_train, method = "class", minsplit = 10,
##     minbucket = 3)
##   n= 169826
##
##           CP nsplit rel error    xerror        xstd
## 1 0.17875874      0 1.0000000 1.0000000 0.006532547
## 2 0.02093046      2 0.6424825 0.6447164 0.005372291
## 3 0.01568570      3 0.6215521 0.6299048 0.005315392
## 4 0.01534577      4 0.6058664 0.6039724 0.005213680
## 5 0.01432595      5 0.5905206 0.5903263 0.005159044
## 6 0.01000000      6 0.5761946 0.5788656 0.005112541
##
## Variable importance
##   num_previous_bills           tot_amount dollars_owed_per_day
##                   52                   27                   13
##     discount_pct_off
##                    7
##
## Node number 1: 169826 observations,    complexity param=0.1787587
##   predicted class=0  expected loss=0.1212535  P(node) =1
##     class counts: 149234 20592
##    probabilities: 0.879 0.121
##   left son=2 (144435 obs) right son=3 (25391 obs)
##   Primary splits:
##       num_previous_bills           < 3954.5   to the left,  improve=9717.5690, (0 missing)
##       discount_pct_off             splits as  RLLLRL,       improve=6773.1310, (0 missing)
##       tot_amount                   < 99620.34 to the left,  improve=4717.4090, (0 missing)
##       dollars_owed_per_day         < 99609.3  to the left,  improve=1034.9520, (0 missing)
##       discount_days_until_discount splits as  -LL-LLLR,     improve= 176.6618, (1003 missing)
##   Surrogate splits:
##       tot_amount           < 157528.8 to the left,  agree=0.852, adj=0.009, (0 split)
##       dollars_owed_per_day < 154799.4 to the left,  agree=0.851, adj=0.002, (0 split)
```

```
##
## Node number 2: 144435 observations,    complexity param=0.02093046
##   predicted class=0  expected loss=0.05033406  P(node) =0.8504881
##     class counts: 137165  7270
##    probabilities: 0.950 0.050
##   left son=4 (140944 obs) right son=5 (3491 obs)
##   Primary splits:
##       tot_amount                   < 99909.62 to the left,  improve=1871.20100, (0 missing)
##       discount_pct_off             splits as  RLRLRL,       improve= 962.25250, (0 missing)
##       num_previous_bills           < 2085.5   to the left,  improve= 687.31030, (0 missing)
##       dollars_owed_per_day         < 99848.87 to the left,  improve= 395.72770, (0 missing)
##       discount_days_until_discount splits as  -LL-LLLR,     improve=  27.13972, (1003 missing)
##   Surrogate splits:
##       dollars_owed_per_day < 99908.73 to the left,  agree=0.982, adj=0.248, (0 split)
##
## Node number 3: 25391 observations,    complexity param=0.1787587
##   predicted class=1  expected loss=0.4753259  P(node) =0.1495119
##     class counts: 12069 13322
##    probabilities: 0.475 0.525
##   left son=6 (12465 obs) right son=7 (12926 obs)
##   Primary splits:
##       tot_amount           < 99476.71 to the left,  improve=3562.583000, (0 missing)
##       discount_pct_off     splits as  ---LR-,       improve=2842.527000, (0 missing)
##       dollars_owed_per_day < 3315.872 to the left,  improve=1397.753000, (0 missing)
##       num_previous_bills   < 13780    to the right, improve= 220.479200, (0 missing)
##       num_days_to_pay      < 160      to the left,  improve=   1.355768, (0 missing)
##   Surrogate splits:
##       dollars_owed_per_day < 3315.89  to the left,  agree=0.814, adj=0.621, (0 split)
##       discount_pct_off     splits as  ---LR-,       agree=0.655, adj=0.298, (0 split)
##       num_previous_bills   < 9694.5   to the left,  agree=0.539, adj=0.060, (0 split)
##       num_days_to_pay      < 61.5     to the right, agree=0.509, adj=0.001, (0 split)
##
## Node number 4: 140944 observations
##   predicted class=0  expected loss=0.03766744  P(node) =0.8299318
##     class counts: 135635  5309
##    probabilities: 0.962 0.038
##
## Node number 5: 3491 observations,    complexity param=0.01534577
##   predicted class=1  expected loss=0.4382698  P(node) =0.02055633
##     class counts:  1530  1961
##    probabilities: 0.438 0.562
##   left son=10 (2422 obs) right son=11 (1069 obs)
##   Primary splits:
##       num_previous_bills   < 695.5    to the left,  improve=255.004500, (0 missing)
##       tot_amount           < 100885.2 to the right, improve= 29.574200, (0 missing)
##       dollars_owed_per_day < 3362.839 to the right, improve= 15.664890, (0 missing)
##       num_days_to_pay      < 4        to the left,  improve=  3.326372, (0 missing)
##       discount_pct_off     splits as  -R-RRL,       improve=  2.755896, (0 missing)
##   Surrogate splits:
##       tot_amount           < 116152.5 to the left,  agree=0.737, adj=0.140, (0 split)
##       dollars_owed_per_day < 115939   to the left,  agree=0.707, adj=0.044, (0 split)
##
## Node number 6: 12465 observations
##   predicted class=0  expected loss=0.2549539  P(node) =0.07339866
```

```
##     class counts:  9287  3178
##    probabilities: 0.745 0.255
##
## Node number 7: 12926 observations,    complexity param=0.0156857
##   predicted class=1  expected loss=0.2152251  P(node) =0.0761132
##     class counts:  2782 10144
##    probabilities: 0.215 0.785
##   left son=14 (491 obs) right son=15 (12435 obs)
##   Primary splits:
##       num_previous_bills   < 13780    to the right, improve=384.4463000, (0 missing)
##       discount_pct_off     splits as  ---LR-,       improve=371.8507000, (0 missing)
##       tot_amount           < 99531.44 to the left,  improve=131.7992000, (0 missing)
##       dollars_owed_per_day < 3317.715 to the left,  improve= 43.7600100, (0 missing)
##       num_days_to_pay      < 106      to the right, improve=  0.9736127, (0 missing)
##
## Node number 10: 2422 observations
##   predicted class=0  expected loss=0.4347647  P(node) =0.01426166
##     class counts:  1369  1053
##    probabilities: 0.565 0.435
##
## Node number 11: 1069 observations
##   predicted class=1  expected loss=0.150608  P(node) =0.006294678
##     class counts:   161   908
##    probabilities: 0.151 0.849
##
## Node number 14: 491 observations
##   predicted class=0  expected loss=0.1710794  P(node) =0.002891195
##     class counts:   407    84
##    probabilities: 0.829 0.171
##
## Node number 15: 12435 observations,    complexity param=0.01432595
##   predicted class=1  expected loss=0.1909932  P(node) =0.073222
##     class counts:  2375 10060
##    probabilities: 0.191 0.809
##   left son=30 (295 obs) right son=31 (12140 obs)
##   Primary splits:
##       discount_pct_off     splits as  ---LR-,       improve=395.533700, (0 missing)
##       num_previous_bills   < 5770.5   to the left,  improve=315.536400, (0 missing)
##       tot_amount           < 99531.44 to the left,  improve=150.187700, (0 missing)
##       dollars_owed_per_day < 3317.715 to the left,  improve= 49.095040, (0 missing)
##       num_days_to_pay      < 106      to the right, improve=  1.146376, (0 missing)
##
## Node number 30: 295 observations
##   predicted class=0  expected loss=0  P(node) =0.001737072
##     class counts:   295     0
##    probabilities: 1.000 0.000
##
## Node number 31: 12140 observations
##   predicted class=1  expected loss=0.1713344  P(node) =0.07148493
##     class counts:  2080 10060
##    probabilities: 0.171 0.829
```

For those of you who installed `YARF`, print out an image of the tree.

```r
#TO-DO
prp(classification_tree_mod)
```



Predict on the test set and report the misclassifcation error

```r
#TO-DO
yhat_train = predict(classification_tree_mod, data = bills_data_train, type = "class")


table(ytrain, yhat_train)
```

```
##        yhat_train
## ytrain      0      1
##      0 146993   2241
##      1   9624  10968
```

```r
yhat_test = predict(classification_tree_mod, newdata = bills_data_test, type = "class")
table(ytest, yhat_test)
```

```
##      yhat_test
## ytest     0     1
##     0 49110   717
##     1  3149  3632
```

Everything below here is due with lab 9

Report the following error metrics: misclassifcation error, precision, recall, F1, FDR, FOR. and compute a confusion matrix.

```
#TO-DO

mean(ytest != yhat_test)
```

```
## [1] 0.06829423
```

```
confusion_matrix = table(ytest,yhat_test)
precision = confusion_matrix[2, 2]/ sum(confusion_matrix[,2])
recall = confusion_matrix[2, 2]/ sum(confusion_matrix[2,])
F1 = 2 / (1/recall+1/ precision)
FDR = confusion_matrix[1, 2]/ sum(confusion_matrix[,2])
FOR = confusion_matrix[2, 1]/ sum(confusion_matrix[,1])
print('oos_ME')
```

```
## [1] "oos_ME"
```

```
mean(ytest != yhat_test)
```

```
## [1] 0.06829423
```

```
print('confusion_matrix')
```

```
## [1] "confusion_matrix"
```

```
confusion_matrix
```

```
##       yhat_test
## ytest     0     1
##     0 49110   717
##     1  3149  3632
```

```
print('precision')
```

```
## [1] "precision"
```

```
precision
```

```
## [1] 0.8351345
```

```
print('recall')
```

```
## [1] "recall"
```

```
recall
```

```
## [1] 0.5356142
```

```
print('F1')
```

```
## [1] "F1"
```

```
F1
```

```
## [1] 0.6526505
```

```
print('FDR')
```

```
## [1] "FDR"
```

```
FDR
```

```
## [1] 0.1648655
```

```
print('FOR')
```

```
## [1] "FOR"
```

```
FOR
```

```
## [1] 0.06025756
```

Is this a good model? (yes/no and explain).

I think it's pretty decent, our false negative rate is 3.8% and our false positive rate is only 12.8%

There are probability asymmetric costs to the two types of errors. Assign the costs below and calculate oos total cost.

```
#TO-DO

Cfn = 10000 #how much we can sell the debt for
Cfp = 50000 # how much the actual debt is
Cfn * confusion_matrix[2,1] + (Cfp * confusion_matrix[1, 2])
```

```
## [1] 67340000
```

We now wish to do asymmetric cost classification. Fit a logistic regression model to this data.

```r
#TO-DO
compute_metrics_prob_classifier = function(p_hats, y_true, res = 0.001){
  #we first make the grid of all prob thresholds
  p_thresholds = seq(0 + res, 1 - res, by = res) #values of 0 or 1 are trivial

  #now we create a matrix which will house all of our results
  performance_metrics = matrix(NA, nrow = length(p_thresholds), ncol = 12)
  colnames(performance_metrics) = c(
    "p_th",
    "TN",
    "FP",
    "FN",
    "TP",
    "miscl_err",
    "precision",
    "recall",
    "FDR",
    "FPR",
    "FOR",
    "miss_rate"
  )

  #now we iterate through each p_th and calculate all metrics about the classifier and save
  n = length(y_true)
  for (i in 1 : length(p_thresholds)){
    p_th = p_thresholds[i]
    y_hats = factor(ifelse(p_hats >= p_th, "0", "1"))
    confusion_table = table(
      factor(y_true, levels = c("1", "0")),
      factor(y_hats, levels = c("1", "0"))
    )

    fp = confusion_table[1, 2]
    fn = confusion_table[2, 1]
    tp = confusion_table[2, 2]
    tn = confusion_table[1, 1]
    npp = sum(confusion_table[, 2])
    npn = sum(confusion_table[, 1])
    np = sum(confusion_table[2, ])
    nn = sum(confusion_table[1, ])

    performance_metrics[i, ] = c(
      p_th,
      tn,
      fp,
      fn,
      tp,
      (fp + fn) / n,
      tp / npp, #precision
      tp / np,  #recall
      fp / npp, #false discovery rate (FDR)
      fp / nn,  #false positive rate (FPR)
      fn / npn, #false omission rate (FOR)
```

```
      fn / np   #miss rate
    )
  }

  #finally return the matrix
  performance_metrics
}
logistic_model = glm(paid_in_full ~., bills_data_train, family = "binomial")
```

Use the function from class to calculate all the error metrics for the values of the probability threshold being 0.001, 0.002, . . . , 0.999 in a data frame.

```
#TO-DO
bills_data_test = na.omit(bills_data_test)
p_hats = predict(logistic_model, bills_data_test, type = "response")
results_table = compute_metrics_prob_classifier(p_hats, bills_data_test$paid_in_full, res = 0.001)
results_table
```

```
##          p_th  TN   FP    FN    TP miscl_err  precision       recall       FDR
##    [1,] 0.001   0 6771   604 48923 0.1309993 0.87842496 9.878046e-01 0.1215750
##    [2,] 0.002   0 6771   604 48923 0.1309993 0.87842496 9.878046e-01 0.1215750
##    [3,] 0.003   0 6771   604 48923 0.1309993 0.87842496 9.878046e-01 0.1215750
##    [4,] 0.004   0 6771   605 48922 0.1310171 0.87842278 9.877844e-01 0.1215772
##    [5,] 0.005   0 6771   605 48922 0.1310171 0.87842278 9.877844e-01 0.1215772
##    [6,] 0.006   0 6771   605 48922 0.1310171 0.87842278 9.877844e-01 0.1215772
##    [7,] 0.007  13 6758  1954 47573 0.1547479 0.87561429 9.605468e-01 0.1243857
##    [8,] 0.008  16 6755  2272 47255 0.1603432 0.87493057 9.541260e-01 0.1250694
##    [9,] 0.009  16 6755  2276 47251 0.1604142 0.87492131 9.540453e-01 0.1250787
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## [794,] 0.794 6421  350 49255   272 0.8811148 0.43729904 5.491954e-03 0.5627010
## [795,] 0.795 6426  345 49257   270 0.8810615 0.43902439 5.451572e-03 0.5609756
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## [965,] 0.965 6722   49 49523     4 0.8805286 0.07547170 8.076403e-05 0.9245283
## [966,] 0.966 6722   49 49523     4 0.8805286 0.07547170 8.076403e-05 0.9245283
## [967,] 0.967 6722   49 49523     4 0.8805286 0.07547170 8.076403e-05 0.9245283
## [968,] 0.968 6722   49 49523     4 0.8805286 0.07547170 8.076403e-05 0.9245283
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## [970,] 0.970 6723   48 49523     4 0.8805109 0.07692308 8.076403e-05 0.9230769
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## [975,] 0.975 6726   45 49523     4 0.8804576 0.08163265 8.076403e-05 0.9183673
## [976,] 0.976 6726   45 49523     4 0.8804576 0.08163265 8.076403e-05 0.9183673
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## [979,] 0.979 6731   40 49523     4 0.8803688 0.09090909 8.076403e-05 0.9090909
## [980,] 0.980 6732   39 49523     4 0.8803510 0.09302326 8.076403e-05 0.9069767
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## [984,] 0.984 6735   36 49523     4 0.8802977 0.10000000 8.076403e-05 0.9000000
## [985,] 0.985 6736   35 49523     4 0.8802799 0.10256410 8.076403e-05 0.8974359
## [986,] 0.986 6737   34 49524     3 0.8802799 0.08108108 6.057302e-05 0.9189189
## [987,] 0.987 6737   34 49525     2 0.8802977 0.05555556 4.038201e-05 0.9444444
## [988,] 0.988 6738   33 49525     2 0.8802799 0.05714286 4.038201e-05 0.9428571
## [989,] 0.989 6738   33 49525     2 0.8802799 0.05714286 4.038201e-05 0.9428571
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## [991,] 0.991 6739   32 49525     2 0.8802622 0.05882353 4.038201e-05 0.9411765
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## [998,] 0.998 6755   16 49525     2 0.8799780 0.11111111 4.038201e-05 0.8888889
## [999,] 0.999 6760   11 49525     2 0.8798892 0.15384615 4.038201e-05 0.8461538
##                FPR       FOR  miss_rate
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##    [2,] 1.000000000 1.0000000 0.01219537
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##    [6,] 1.000000000 1.0000000 0.01221556
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##   [943,] 0.009304386 0.8807043 0.99989904
##   [944,] 0.009304386 0.8807043 0.99989904
##   [945,] 0.009304386 0.8807043 0.99989904
##   [946,] 0.009304386 0.8807043 0.99989904
##   [947,] 0.009304386 0.8807043 0.99989904
##   [948,] 0.009304386 0.8807043 0.99989904
##   [949,] 0.009304386 0.8807043 0.99989904
##   [950,] 0.009304386 0.8807043 0.99989904
##   [951,] 0.009304386 0.8807043 0.99989904
##   [952,] 0.009304386 0.8807043 0.99989904
##   [953,] 0.009156698 0.8806886 0.99989904
##   [954,] 0.009009009 0.8806729 0.99989904
##   [955,] 0.008713632 0.8806416 0.99989904
##   [956,] 0.008565943 0.8806259 0.99989904
##   [957,] 0.008270566 0.8805946 0.99989904
##   [958,] 0.008270566 0.8805946 0.99989904
##   [959,] 0.007827500 0.8805477 0.99989904
##   [960,] 0.007827500 0.8805477 0.99989904
##   [961,] 0.007679811 0.8805320 0.99989904
##   [962,] 0.007532122 0.8805163 0.99989904
##   [963,] 0.007532122 0.8805163 0.99989904
##   [964,] 0.007236745 0.8804850 0.99989904
##   [965,] 0.007236745 0.8804872 0.99991924
##   [966,] 0.007236745 0.8804872 0.99991924
##   [967,] 0.007236745 0.8804872 0.99991924
##   [968,] 0.007236745 0.8804872 0.99991924
##   [969,] 0.007089056 0.8804715 0.99991924
##   [970,] 0.007089056 0.8804715 0.99991924
##   [971,] 0.006941368 0.8804558 0.99991924
##   [972,] 0.006941368 0.8804558 0.99991924
##   [973,] 0.006941368 0.8804558 0.99991924
##   [974,] 0.006941368 0.8804558 0.99991924
##   [975,] 0.006645990 0.8804245 0.99991924
##   [976,] 0.006645990 0.8804245 0.99991924
##   [977,] 0.006350613 0.8803932 0.99991924
##   [978,] 0.006055236 0.8803619 0.99991924
```

```
##  [979,] 0.005907547 0.8803463 0.99991924
##  [980,] 0.005759858 0.8803306 0.99991924
##  [981,] 0.005759858 0.8803306 0.99991924
##  [982,] 0.005759858 0.8803306 0.99991924
##  [983,] 0.005759858 0.8803306 0.99991924
##  [984,] 0.005316792 0.8802837 0.99991924
##  [985,] 0.005169104 0.8802680 0.99991924
##  [986,] 0.005021415 0.8802545 0.99993943
##  [987,] 0.005021415 0.8802567 0.99995962
##  [988,] 0.004873726 0.8802410 0.99995962
##  [989,] 0.004873726 0.8802410 0.99995962
##  [990,] 0.004873726 0.8802410 0.99995962
##  [991,] 0.004726038 0.8802254 0.99995962
##  [992,] 0.004578349 0.8802097 0.99995962
##  [993,] 0.004430660 0.8801941 0.99995962
##  [994,] 0.004282971 0.8801784 0.99995962
##  [995,] 0.003839905 0.8801315 0.99995962
##  [996,] 0.002953773 0.8800377 0.99995962
##  [997,] 0.002953773 0.8800377 0.99995962
##  [998,] 0.002363019 0.8799751 0.99995962
##  [999,] 0.001624575 0.8798970 0.99995962
```

Calculate the column `total_cost` and append it to this data frame.

```
#TO-DO
results_table = data.table(results_table)
results_table[,total_cost := Cfn * FN + Cfp * FP]
results_table
```

```
##       p_th   TN   FP    FN    TP miscl_err  precision       recall       FDR
##    1: 0.001    0 6771   604 48923 0.1309993 0.87842496 9.878046e-01 0.1215750
##    2: 0.002    0 6771   604 48923 0.1309993 0.87842496 9.878046e-01 0.1215750
##    3: 0.003    0 6771   604 48923 0.1309993 0.87842496 9.878046e-01 0.1215750
##    4: 0.004    0 6771   605 48922 0.1310171 0.87842278 9.877844e-01 0.1215772
##    5: 0.005    0 6771   605 48922 0.1310171 0.87842278 9.877844e-01 0.1215772
##  ---
## 995: 0.995 6745   26 49525     2 0.8801556 0.07142857 4.038201e-05 0.9285714
## 996: 0.996 6751   20 49525     2 0.8800490 0.09090909 4.038201e-05 0.9090909
## 997: 0.997 6751   20 49525     2 0.8800490 0.09090909 4.038201e-05 0.9090909
## 998: 0.998 6755   16 49525     2 0.8799780 0.11111111 4.038201e-05 0.8888889
## 999: 0.999 6760   11 49525     2 0.8798892 0.15384615 4.038201e-05 0.8461538
##              FPR       FOR  miss_rate total_cost
##    1: 1.000000000 1.0000000 0.01219537  344590000
##    2: 1.000000000 1.0000000 0.01219537  344590000
##    3: 1.000000000 1.0000000 0.01219537  344590000
##    4: 1.000000000 1.0000000 0.01221556  344600000
##    5: 1.000000000 1.0000000 0.01221556  344600000
##  ---
## 995: 0.003839905 0.8801315 0.99995962  496550000
## 996: 0.002953773 0.8800377 0.99995962  496250000
## 997: 0.002953773 0.8800377 0.99995962  496250000
## 998: 0.002363019 0.8799751 0.99995962  496050000
## 999: 0.001624575 0.8798970 0.99995962  495800000
```

Which is the winning probability threshold value and the total cost at that threshold?

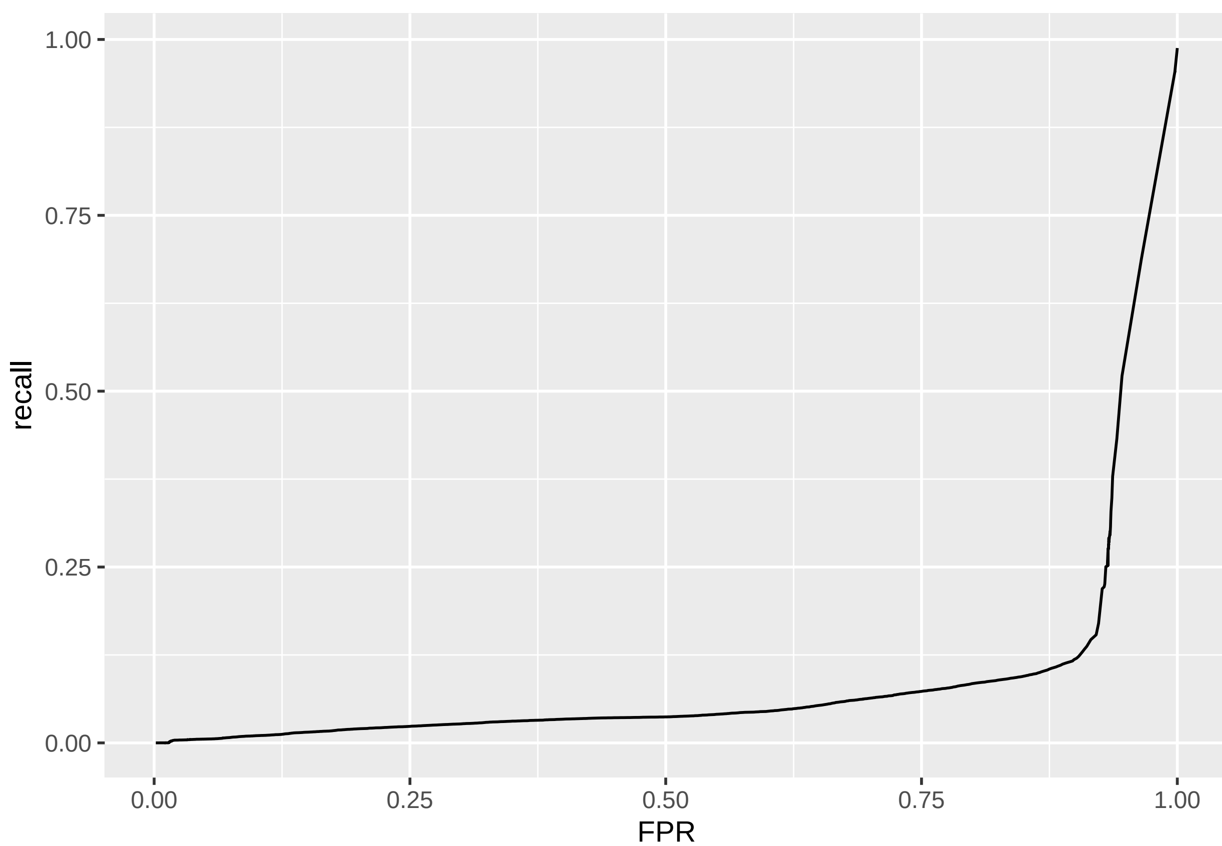
```
#TO-DO

results_table[min(total_cost)== total_cost ]
```

```
##     p_th TN   FP  FN    TP miscl_err precision    recall      FDR FPR FOR
## 1: 0.001  0 6771 604 48923 0.1309993  0.878425 0.9878046 0.121575   1   1
## 2: 0.002  0 6771 604 48923 0.1309993  0.878425 0.9878046 0.121575   1   1
## 3: 0.003  0 6771 604 48923 0.1309993  0.878425 0.9878046 0.121575   1   1
##     miss_rate total_cost
## 1: 0.01219537  344590000
## 2: 0.01219537  344590000
## 3: 0.01219537  344590000
```

Plot an ROC curve and interpret.

```
#TO-DO
pacman::p_load(ggplot2)
ggplot(results_table) +
  geom_line(aes(x = FPR, y = recall))
```




```
  #geom_abline(intercept = 0, slope = 1, col = "orange") +
  #coord_fixed() + xlim(0, 1) + ylim(0, 1)
```

#TO-DO interpretation

Calculate AUC and interpret.

```r
#TO-DO
pacman::p_load(pracma)
-trapz(results_table$FPR, results_table$recall)
```

```
## [1] 0.08890393
```

#TO-DO interpretation

Plot a DET curve and interpret.

```r
#TO-DO
ggplot(results_table)+
  geom_line(aes(x=FDR, y= FOR))
```