

# Model Selection - readmission\_60d

Eduardo Yuki Yada

## Imports

```
library(tidyverse)
library(yaml)
library(tidymodels)
library(usemodels)
library(vip)
library(bonsai)
library(lightgbm)
library(caret)
```

Minutes to run: 0

## Loading data

```
load('dataset/processed_data.RData')
load('dataset/processed_dictionary.RData')

columns_list <- yaml.load_file("./auxiliar/columns_list.yaml")

outcome_column <- params$outcome_column
features_list <- params$features_list

df <- mutate(df, across(where(is.character), as.factor))
```

Minutes to run: 0.005

```
dir.create(file.path("./auxiliar/model_selection/hyperparameters/"),
           showWarnings = FALSE,
           recursive = TRUE)

dir.create(file.path("./auxiliar/model_selection/performance/"),
           showWarnings = FALSE,
           recursive = TRUE)
```

Minutes to run: 0

## Eligible features

```
eligible_columns = df_names %>%
  filter(momento.aquisicao == 'Admissão t0') %>%
  .$variable.name

exception_columns = c('death_intraop', 'death_intraop_1')

correlated_columns = c('year_procedure_1', # com year_adm_t0
                       'age_surgery_1', # com age
                       'admission_t0', # com admission_pre_t0_count
                       'atb', # com meds_antimicrobianos
                       'classe_meds_cardio_qtde', # com classe_meds_qtde)
```

```

        'suporte_hemod' # com proced_invasivos_qtde
    )

eligible_features = eligible_columns %>%
  base::intersect(c(columns_list$categorical_columns, columns_list$numerical_columns)) %>%
  setdiff(c(exception_columns, correlated_columns))

if (is.null(features_list)) {
  features = eligible_features
} else {
  features = base::intersect(eligible_features, features_list)
}

gluedown::md_order(features, seq = TRUE, pad = TRUE)

## 01. age
## 02. education_level
## 03. underlying_heart_disease
## 04. heart_disease
## 05. nyha_basal
## 06. prior_mi
## 07. heart_failure
## 08. af
## 09. cardiac_arrest
## 10. transplant
## 11. valvopathy
## 12. diabetes
## 13. hemodialysis
## 14. comorbidities_count
## 15. procedure_type_1
## 16. reop_type_1
## 17. procedure_type_new
## 18. cied_final_1
## 19. cied_final_group_1
## 20. admission_pre_t0_count
## 21. admission_pre_t0_180d
## 22. icu_t0
## 23. dialysis_t0
## 24. admission_t0_emergency
## 25. aco
## 26. antiarritmico
## 27. betabloqueador
## 28. ieca_bra
## 29. dva
## 30. digoxina
## 31. estatina
## 32. diuretico
## 33. vasodilatador
## 34. insuf_cardiaca
## 35. espironolactona
## 36. bloq_calcio
## 37. antiplaquetario_ev
## 38. insulina
## 39. anticonvulsivante
## 40. psicofarmacos
## 41. antifungico
## 42. antiviral
## 43. classe_meds_qtde
## 44. meds_cardiovasc_qtde
## 45. meds_antimicrobianos
## 46. cec

```

```
## 47. transplante_cardiaco
## 48. cir_toracica
## 49. outros_proced_cirurgicos
## 50. icp
## 51. angioplastia
## 52. cateterismo
## 53. eletrofisiologia
## 54. cateter_venoso_central
## 55. proced_invasivos_qtde
## 56. cve_desf
## 57. transfusao
## 58. interconsulta
## 59. equipe_multiprof
## 60. ecg
## 61. holter
## 62. teste_esforco
## 63. espiro_ergoespiro
## 64. tilt_teste
## 65. metodos_graficos_qtde
## 66. laboratorio
## 67. cultura
## 68. analises_clinicas_qtde
## 69. citologia
## 70. biopsia
## 71. histopatologia_qtde
## 72. angio_rm
## 73. angio_tc
## 74. arteriografia
## 75. cintilografia
## 76. ecocardiograma
## 77. endoscopia
## 78. pet_ct
## 79. ultrassom
## 80. tomografia
## 81. radiografia
## 82. ressonancia
## 83. exames_imagem_qtde
## 84. bic
```

Minutes to run: 0

## Train test split (70%/30%)

```
set.seed(42)

if (outcome_column == 'readmission_30d') {
  df_split <- readRDS("./dataset/split_object.rds")
} else {
  df_split <- initial_split(df, prop = .7, strata = all_of(outcome_column))
}

df_train <- training(df_split) %>% dplyr::select(all_of(c(features, outcome_column)))
df_test <- testing(df_split) %>% dplyr::select(all_of(c(features, outcome_column)))
```

Minutes to run: 0.001

## Global parameters

```
k = 5 # Number of folds for cross validation
grid_size = 15 # Number of parameter combination to tune on each model
```

```
set.seed(234)
df_folds <- vfold_cv(df_train, v = k,
                     strata = all_of(outcome_column))
```

Minutes to run: 0

## Functions

```
validation = function(model_fit, new_data, plot=TRUE) {
  library(pROC)
  library(caret)

  test_predictions_prob <-
    predict(model_fit, new_data = new_data, type = "prob") %>%
    rename_at(vars(starts_with(".pred_")), ~ str_remove(., ".pred_")) %>%
    .$`1`

  pROC_obj <- roc(
    new_data[[outcome_column]],
    test_predictions_prob,
    direction = "<",
    levels = c(0, 1),
    smoothed = TRUE,
    ci = TRUE,
    ci.alpha = 0.9,
    stratified = FALSE,
    plot = plot,
    auc.polygon = TRUE,
    max.auc.polygon = TRUE,
    grid = TRUE,
    print.auc = TRUE,
    show.thres = TRUE
  )

  test_predictions_class <-
    predict(model_fit, new_data = new_data, type = "class") %>%
    rename_at(vars(starts_with(".pred_")), ~ str_remove(., ".pred_")) %>%
    .$class

  conf_matrix <- table(test_predictions_class, new_data[[outcome_column]])

  if (plot) {
    sens.ci <- ci.se(pROC_obj)
    plot(sens.ci, type = "shape", col = "lightblue")
    plot(sens.ci, type = "bars")

    confusionMatrix(conf_matrix) %>% print
  }

  return(pROC_obj)
}
```

Minutes to run: 0

## Boosted Tree (XGBoost)

```
xgboost_recipe <-
  recipe(formula = sprintf("%s ~ .", outcome_column) %>% as.formula, data = df_train) %>%
  step_novel(all_nominal_predictors()) %>%
```

```

step_unknown(all_nominal_predictors()) %>%
step_other(all_nominal_predictors(), threshold = 0.05, other=".merged") %>%
step_dummy(all_nominal_predictors(), one_hot = TRUE) %>%
step_zv(all_predictors())

```

```

xgboost_spec <- boost_tree(
  mtry = tune(),
  trees = tune(),
  min_n = tune(),
  tree_depth = tune(),
  learn_rate = tune(),
  loss_reduction = tune()
) %>%
set_engine("xgboost") %>%
set_mode("classification")

```

```

xgboost_grid <- grid_latin_hypercube(
  finalize(mtry(), df_train),
  dials::trees(range = c(100L, 300L)),
  min_n(),
  tree_depth(),
  learn_rate(),
  loss_reduction(),
  size = grid_size
)

```

```

xgboost_workflow <-
  workflow() %>%
  add_recipe(xgboost_recipe) %>%
  add_model(xgboost_spec)

```

```

xgboost_tune <-
  xgboost_workflow %>%
  tune_grid(resamples = df_folds,
            grid = xgboost_grid)

```

```

xgboost_tune %>%
  show_best("roc_auc")

```

```

## # A tibble: 5 x 12
##   mtry trees min_n tree_depth learn_rate loss_re~1 .metric .esti~2 mean      n std_err .config
##   <int> <int> <int>      <int>      <dbl>      <dbl> <chr>      <chr>    <dbl> <int>    <dbl> <chr>
## 1    20   191    21         4  0.0257      2.28e-1 roc_auc binary  0.711     5  0.0103  Prepro~
## 2    40   131    24         9  0.00403     4.87e-4 roc_auc binary  0.708     5  0.00622 Prepro~
## 3    56   245    18        14  0.000812    4.41e-3 roc_auc binary  0.708     5  0.00763 Prepro~
## 4    80   280    29         4  0.00636     3.47e-9 roc_auc binary  0.704     5  0.00792 Prepro~
## 5    35   252    39        14  0.0000379   2.90e-9 roc_auc binary  0.703     5  0.00503 Prepro~
## # ... with abbreviated variable names 1: loss_reduction, 2: .estimator

```

```

best_xgboost <- xgboost_tune %>%
  select_best("roc_auc")

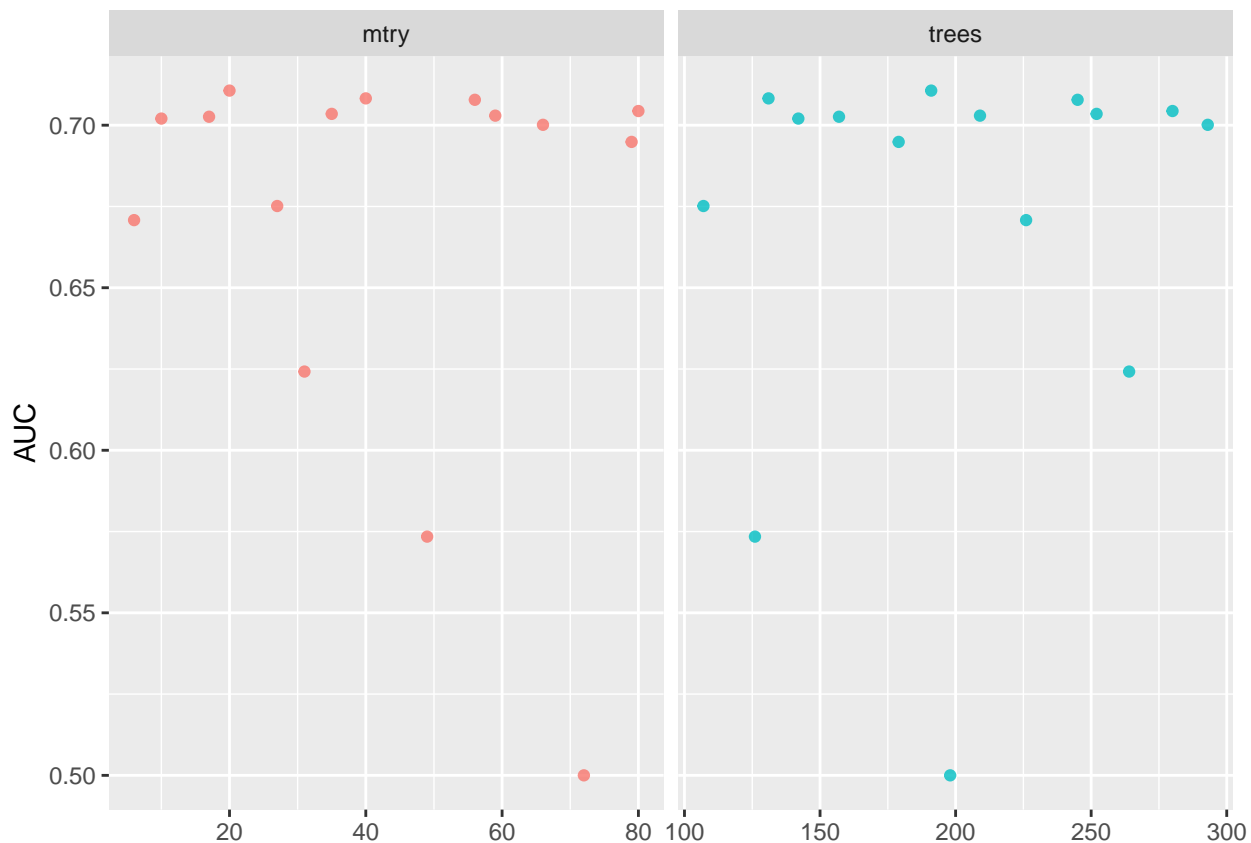
```

```

xgboost_tune %>%
  collect_metrics() %>%
  filter(.metric == "roc_auc") %>%
  select(mean, mtry:trees) %>%
  pivot_longer(mtry:trees,
               values_to = "value",
               names_to = "parameter"
  ) %>%
  ggplot(aes(value, mean, color = parameter)) +

```

```
geom_point(alpha = 0.8, show.legend = FALSE) +
facet_wrap(~parameter, scales = "free_x") +
labs(x = NULL, y = "AUC")
```

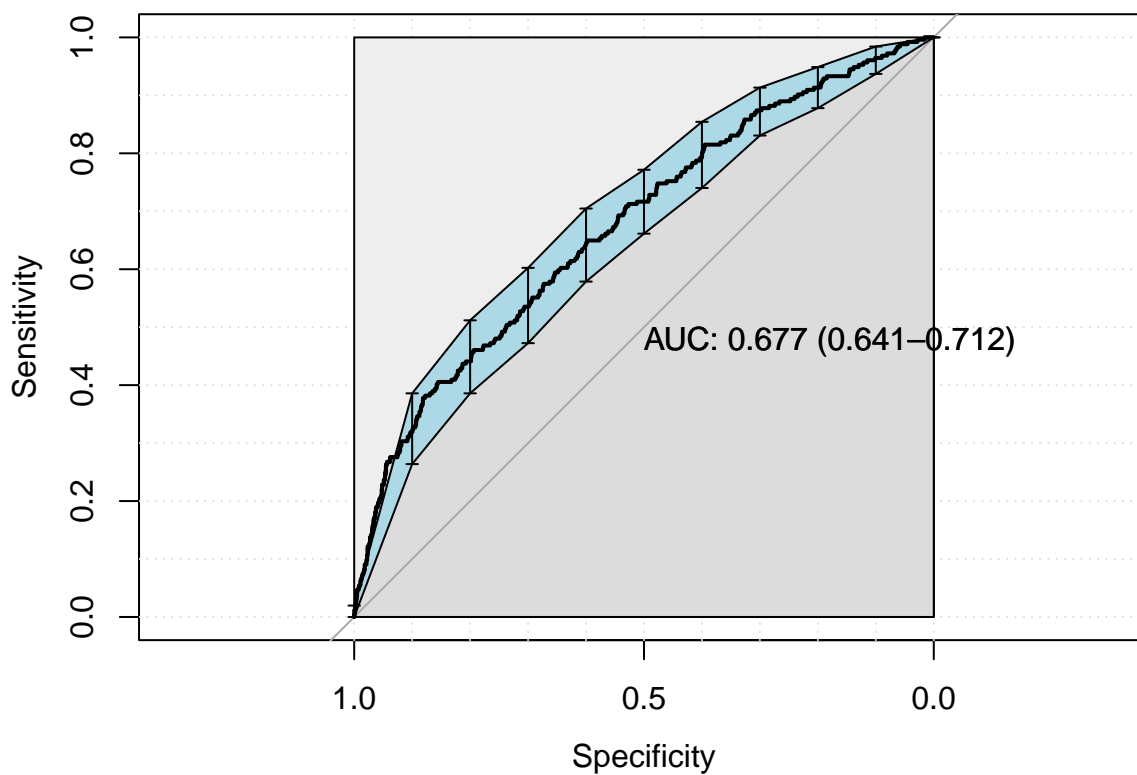


```
final_xgboost_workflow <-
  xgboost_workflow %>%
  finalize_workflow(best_xgboost)

last_xgboost_fit <-
  final_xgboost_workflow %>%
  last_fit(df_split)

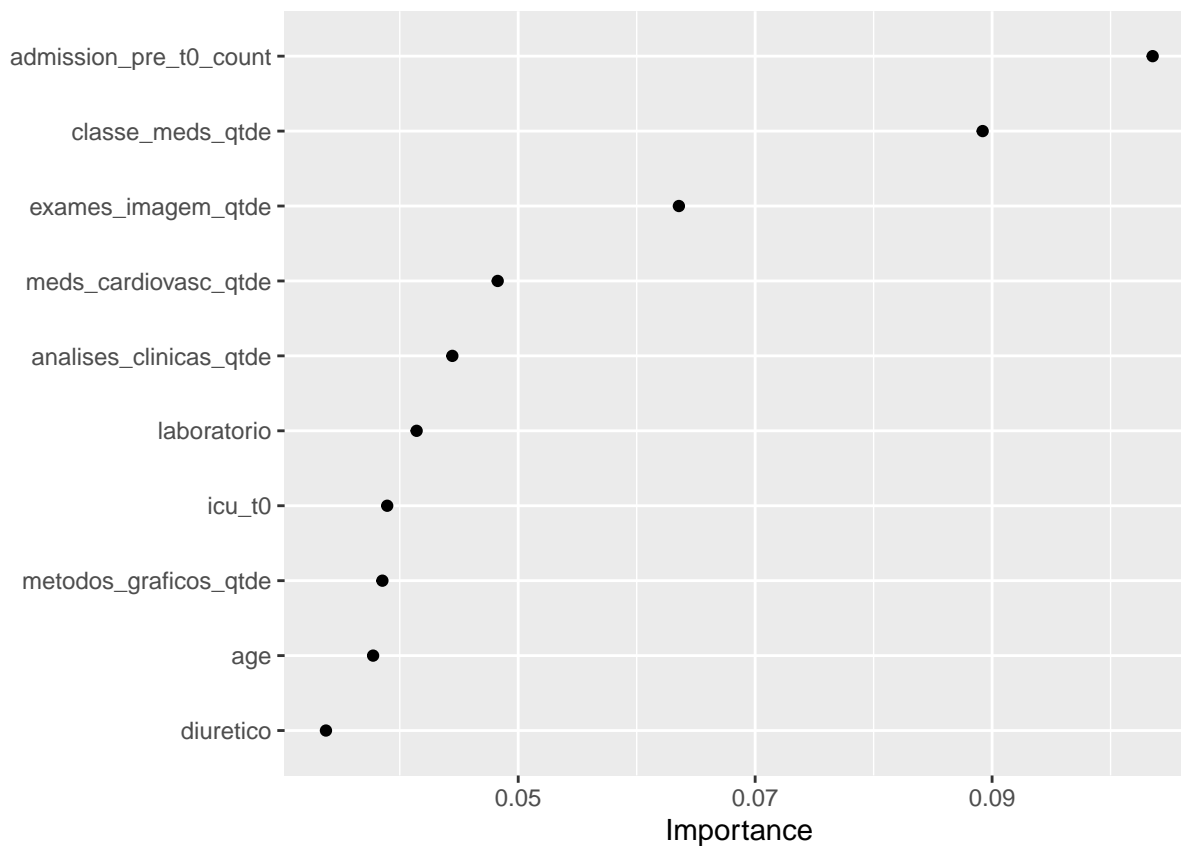
final_xgboost_fit <- extract_workflow(last_xgboost_fit)

xgboost_auc <- validation(final_xgboost_fit, df_test)
```



```
## Confusion Matrix and Statistics
##
##
## test_predictions_class    0    1
##                0 4476  254
##                1    0    0
##
##          Accuracy : 0.9463
##          95% CI   : (0.9395, 0.9526)
##    No Information Rate : 0.9463
##    P-Value [Acc > NIR] : 0.5167
##
##          Kappa : 0
##
##  McNemar's Test P-Value : <2e-16
##
##          Sensitivity : 1.0000
##          Specificity : 0.0000
##    Pos Pred Value : 0.9463
##    Neg Pred Value :      NaN
##    Prevalence : 0.9463
##    Detection Rate : 0.9463
##    Detection Prevalence : 1.0000
##    Balanced Accuracy : 0.5000
##
##    'Positive' Class : 0
##
```

```
final_xgboost_fit %>%
  fit(data = df_train) %>%
  extract_fit_parsnip() %>%
  vip(geom = "point")
```



```
xgboost_parameters <- xgboost_tune %>%
  show_best("roc_auc", n = 1) %>%
  select(trees, mtry, min_n, tree_depth, learn_rate, loss_reduction) %>%
  as.list

saveRDS(
  xgboost_parameters,
  file = sprintf(
    "./auxiliar/model_selection/hyperparameters/xgboost_%s.rds",
    outcome_column
  )
)
```

Minutes to run: 5.971

## Boosted Tree (LightGBM)

```
lightgbm_recipe <-
  recipe(formula = sprintf("%s ~ .", outcome_column) %>% as.formula, data = df_train) %>%
  step_novel(all_nominal_predictors()) %>%
  step_unknown(all_nominal_predictors()) %>%
  step_other(all_nominal_predictors(), threshold = 0.05, other=".merged") %>%
  step_impute_mean(all_numeric_predictors()) %>%
  step_zv(all_predictors())

lightgbm_spec <- boost_tree(
  mtry = tune(),
  trees = tune(),
  min_n = tune(),
  tree_depth = tune(),
  learn_rate = tune(),
  loss_reduction = tune(),
  sample_size = 1
)
```



```

) %>%
  set_engine("lightgbm") %>%
  set_mode("classification")

lightgbm_grid <- grid_latin_hypercube(
  finalize(mtry(), df_train),
  dials::trees(range = c(100L, 300L)),
  min_n(),
  tree_depth(),
  learn_rate(),
  loss_reduction(),
  size = grid_size
)

lightgbm_workflow <-
  workflow() %>%
  add_recipe(lightgbm_recipe) %>%
  add_model(lightgbm_spec)

lightgbm_tune <-
  lightgbm_workflow %>%
  tune_grid(resamples = df_folds,
            grid = lightgbm_grid)

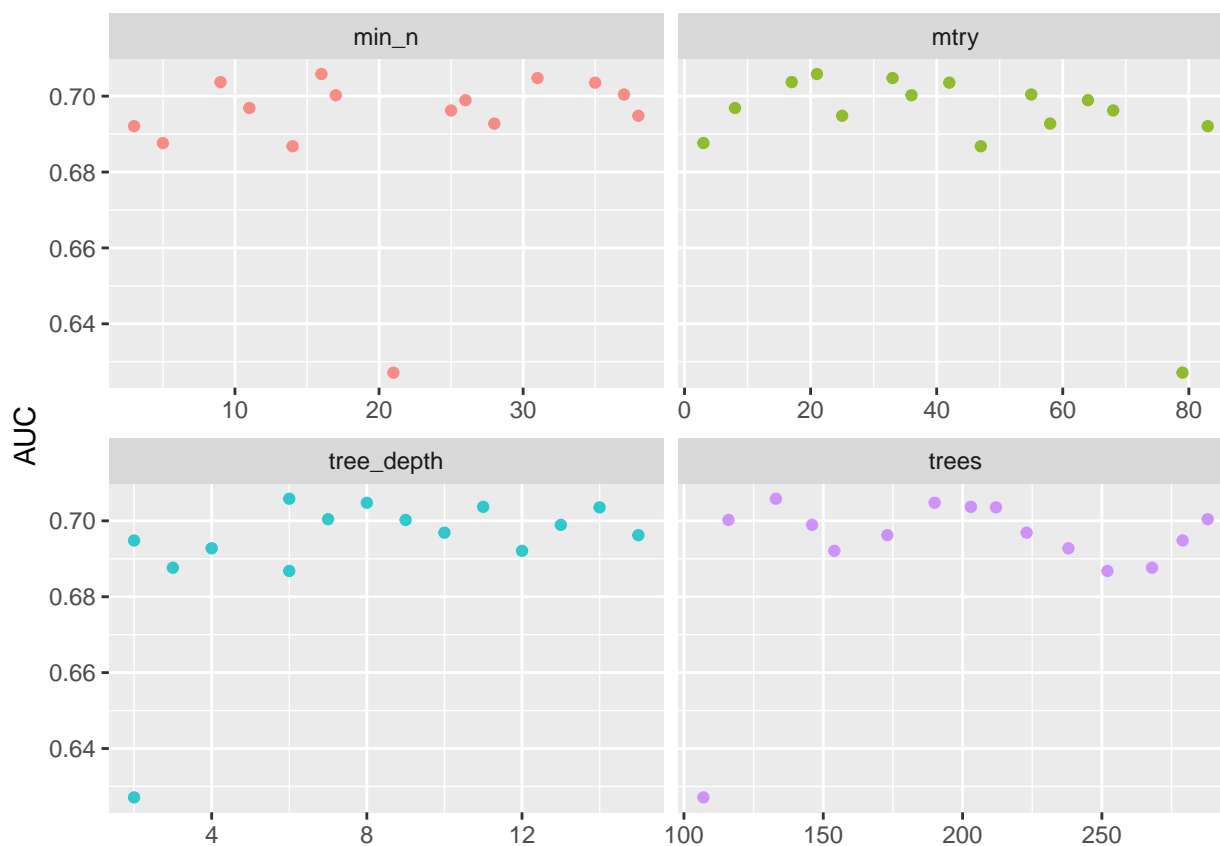
lightgbm_tune %>%
  show_best("roc_auc")

## # A tibble: 5 x 12
##   mtry trees min_n tree_depth learn_rate loss_r~1 .metric .esti~2 mean      n std_err .config
##   <int> <int> <int>      <int>      <dbl>      <dbl> <chr>      <chr>      <dbl> <int>      <dbl> <chr>
## 1     21   133    16         6      5.76e-4  4.82e- 2 roc_auc binary  0.706      5 0.00857 Prepro~
## 2     33   190    31         8      1.39e-8  1.74e-10 roc_auc binary  0.705      5 0.00803 Prepro~
## 3     17   203     9        11      3.02e-5  5.79e- 6 roc_auc binary  0.704      5 0.00788 Prepro~
## 4     42   212    35        14      1.03e-2  5.90e- 4 roc_auc binary  0.704      5 0.0103  Prepro~
## 5     55   288    37         7      2.39e-6  4.95e- 5 roc_auc binary  0.700      5 0.00806 Prepro~
## # ... with abbreviated variable names 1: loss_reduction, 2: .estimator

best_lightgbm <- lightgbm_tune %>%
  select_best("roc_auc")

lightgbm_tune %>%
  collect_metrics() %>%
  filter(.metric == "roc_auc") %>%
  select(mean, mtry:tree_depth) %>%
  pivot_longer(mtry:tree_depth,
               values_to = "value",
               names_to = "parameter"
  ) %>%
  ggplot(aes(value, mean, color = parameter)) +
  geom_point(alpha = 0.8, show.legend = FALSE) +
  facet_wrap(~parameter, scales = "free_x") +
  labs(x = NULL, y = "AUC")

```

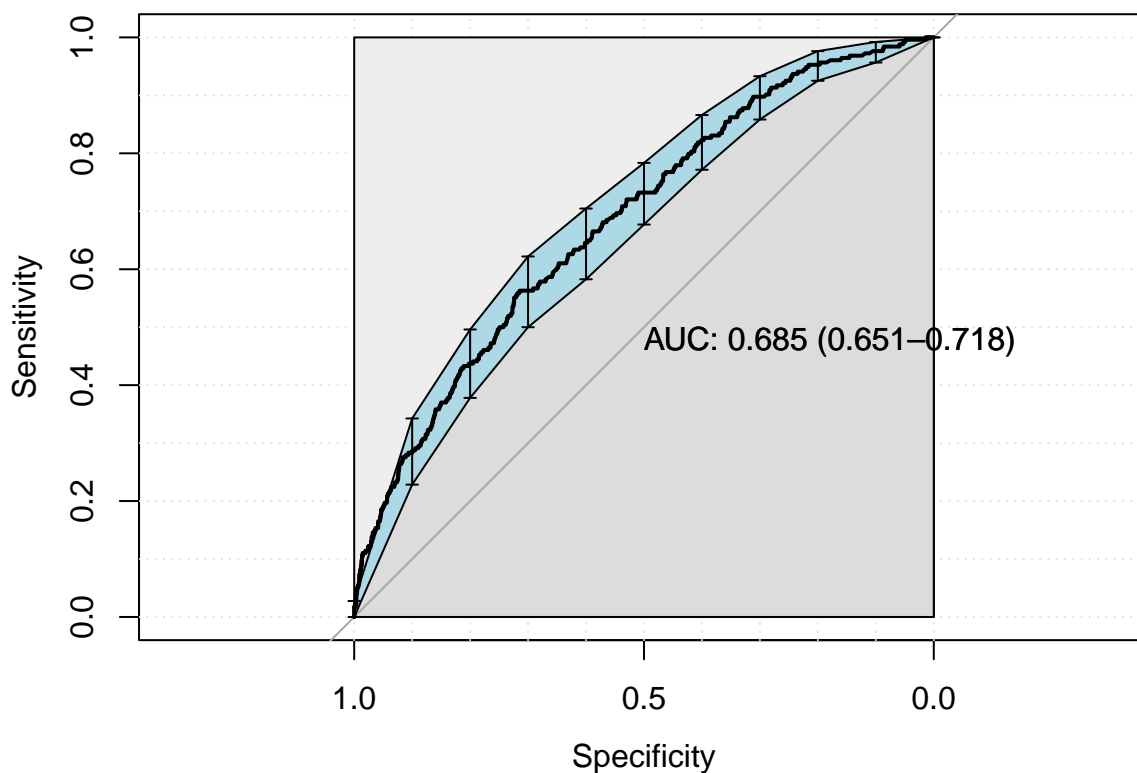


```
final_lightgbm_workflow <-
  lightgbm_workflow %>%
  finalize_workflow(best_lightgbm)

last_lightgbm_fit <-
  final_lightgbm_workflow %>%
  last_fit(df_split)

final_lightgbm_fit <- extract_workflow(last_lightgbm_fit)

lightgbm_auc <- validation(final_lightgbm_fit, df_test)
```



# ``` ## Confusion Matrix and Statistics ```

```
##
##
## test_predictions_class    0    1
##                0 4476  254
##                1    0    0
##
##          Accuracy : 0.9463
##          95% CI   : (0.9395, 0.9526)
##    No Information Rate : 0.9463
##    P-Value [Acc > NIR] : 0.5167
##
##          Kappa : 0
##
## McNemar's Test P-Value : <2e-16
##
##          Sensitivity : 1.0000
##          Specificity : 0.0000
##    Pos Pred Value : 0.9463
##    Neg Pred Value :      NaN
##    Prevalence : 0.9463
##    Detection Rate : 0.9463
##    Detection Prevalence : 1.0000
##    Balanced Accuracy : 0.5000
##
##    'Positive' Class : 0
##
lightgbm_parameters <- lightgbm_tune %>%
  show_best("roc_auc", n=1) %>%
  select(trees, mtry, min_n, tree_depth, learn_rate, loss_reduction) %>%
  as.list

saveRDS(
```

```

lightgbm_parameters,
file = sprintf(
  "./auxiliar/model_selection/hyperparameters/lightgbm_%s.rds",
  outcome_column
)
)

```

Minutes to run: 2.167

## GLM

```

glmnet_recipe <-
  recipe(formula = sprintf("%s ~ .", outcome_column) %>% as.formula, data = df_train) %>%
  step_novel(all_nominal_predictors()) %>%
  step_unknown(all_nominal_predictors()) %>%
  step_other(all_nominal_predictors(), threshold = 0.05, other=".merged") %>%
  step_dummy(all_nominal_predictors(), one_hot = TRUE) %>%
  step_zv(all_predictors()) %>%
  step_normalize(all_numeric_predictors())

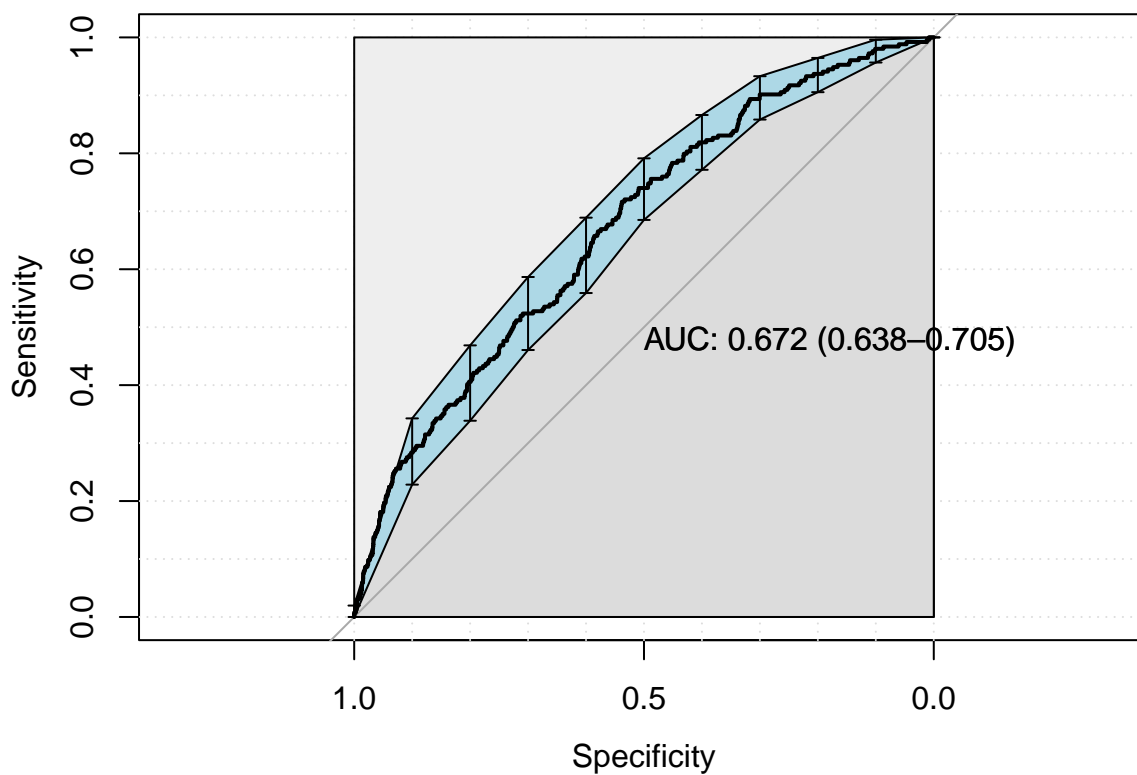
glmnet_spec <-
  logistic_reg(penalty = 0) %>%
  set_mode("classification") %>%
  set_engine("glmnet")

glmnet_workflow <-
  workflow() %>%
  add_recipe(glmnet_recipe) %>%
  add_model(glmnet_spec)

glm_fit <- glmnet_workflow %>%
  fit(df_train)

glm_auc = validation(glm_fit, df_test)

```

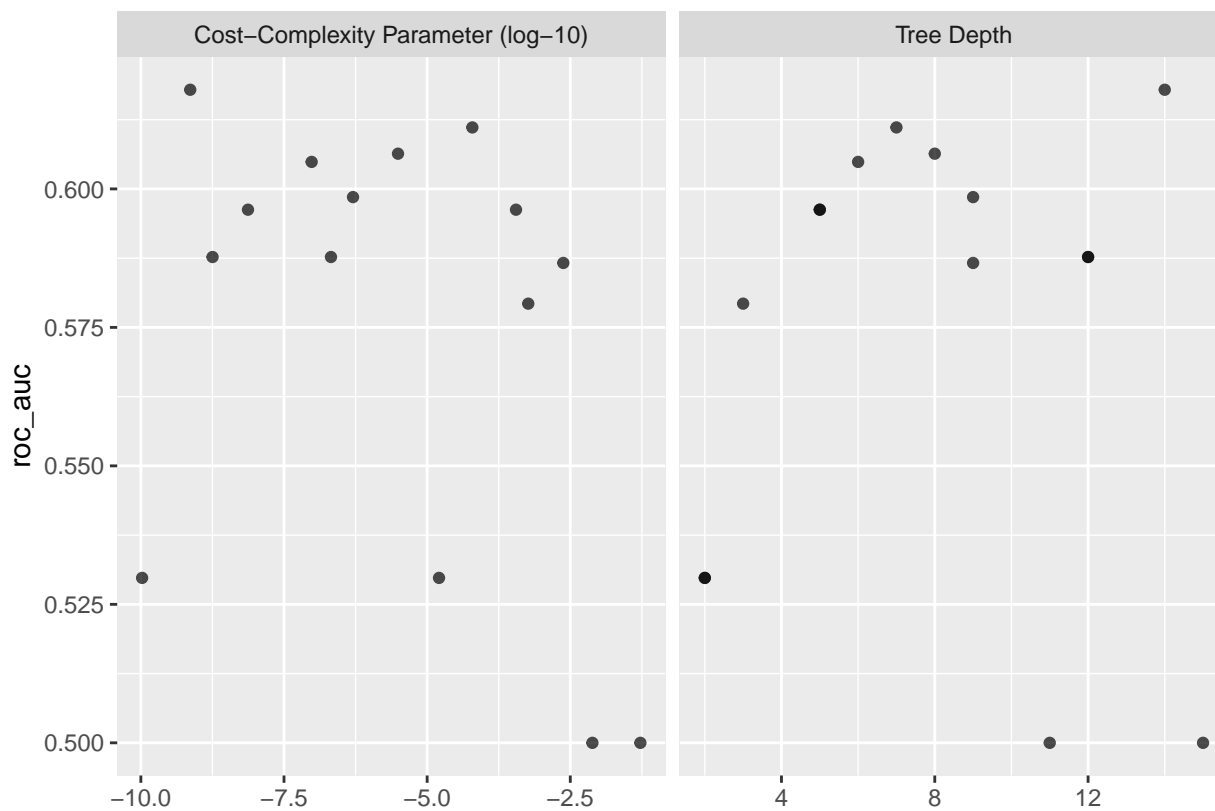


```
## Confusion Matrix and Statistics
##
##
## test_predictions_class    0    1
##                0 4466  252
##                1   10    2
##
##                Accuracy : 0.9446
##                95% CI  : (0.9377, 0.951)
##                No Information Rate : 0.9463
##                P-Value [Acc > NIR] : 0.7105
##
##                Kappa : 0.0102
##
## McNemar's Test P-Value : <2e-16
##
##                Sensitivity : 0.997766
##                Specificity : 0.007874
##                Pos Pred Value : 0.946588
##                Neg Pred Value : 0.166667
##                Prevalence : 0.946300
##                Detection Rate : 0.944186
##                Detection Prevalence : 0.997463
##                Balanced Accuracy : 0.502820
##
##                'Positive' Class : 0
##
```

Minutes to run: 0.157

## Decision Tree

```
tree_recipe <-  
  recipe(formula = sprintf("%s ~ .", outcome_column) %>% as.formula, data = df_train) %>%  
  step_nominal(all_nominal_predictors()) %>%  
  step_unknown(all_nominal_predictors()) %>%  
  step_other(all_nominal_predictors(), threshold = 0.05, other=".merged") %>%  
  step_dummy(all_nominal_predictors(), one_hot = TRUE) %>%  
  step_zv(all_predictors())  
  
tree_spec <-  
  decision_tree(cost_complexity = tune(),  
                tree_depth = tune()) %>%  
  set_mode("classification") %>%  
  set_engine("rpart")  
  
tree_grid <- grid_latin_hypercube(cost_complexity(),  
                                  tree_depth(),  
                                  size = grid_size)  
  
tree_workflow <-  
  workflow() %>%  
  add_recipe(tree_recipe) %>%  
  add_model(tree_spec)  
  
tree_tune <-  
  tree_workflow %>%  
  tune_grid(resamples = df_folds,  
            grid = tree_grid)  
  
tree_tune %>%  
  collect_metrics()  
  
autoplot(tree_tune, metric = "roc_auc")
```



```
tree_tune %>%
  show_best("roc_auc")

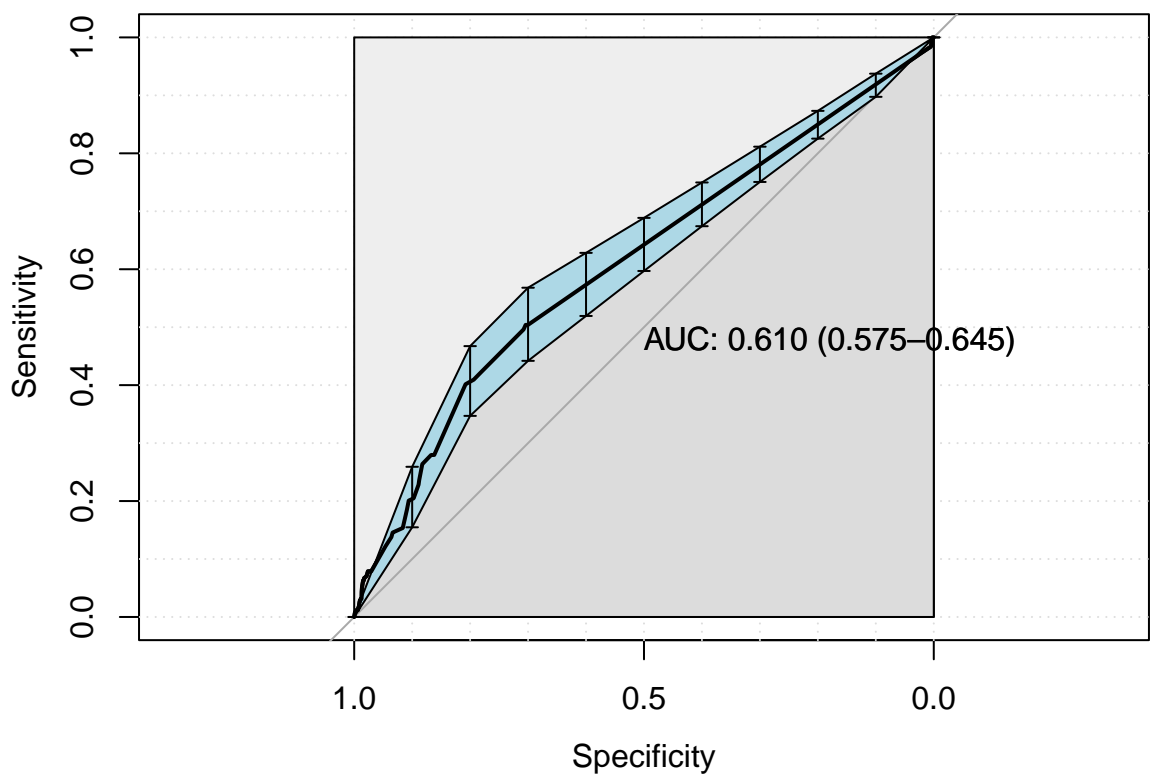
best_tree <- tree_tune %>%
  select_best("roc_auc")

final_tree_workflow <-
  tree_workflow %>%
  finalize_workflow(best_tree)

last_tree_fit <-
  final_tree_workflow %>%
  last_fit(df_split)

final_tree_fit <- extract_workflow(last_tree_fit)

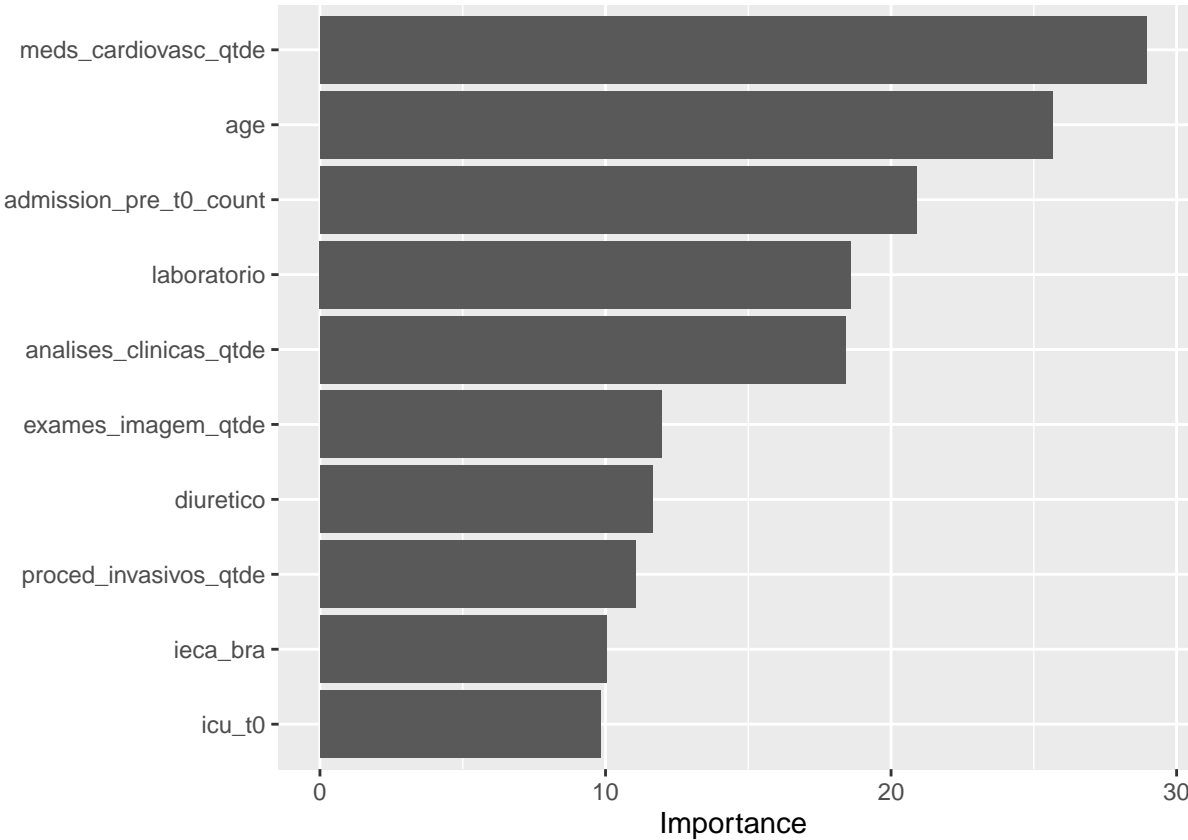
tree_auc = validation(final_tree_fit, df_test)
```



```

if (tree_auc$auc > 0.55){
  final_tree_fit %>%
    extract_fit_parsnip() %>%
    vip()
}

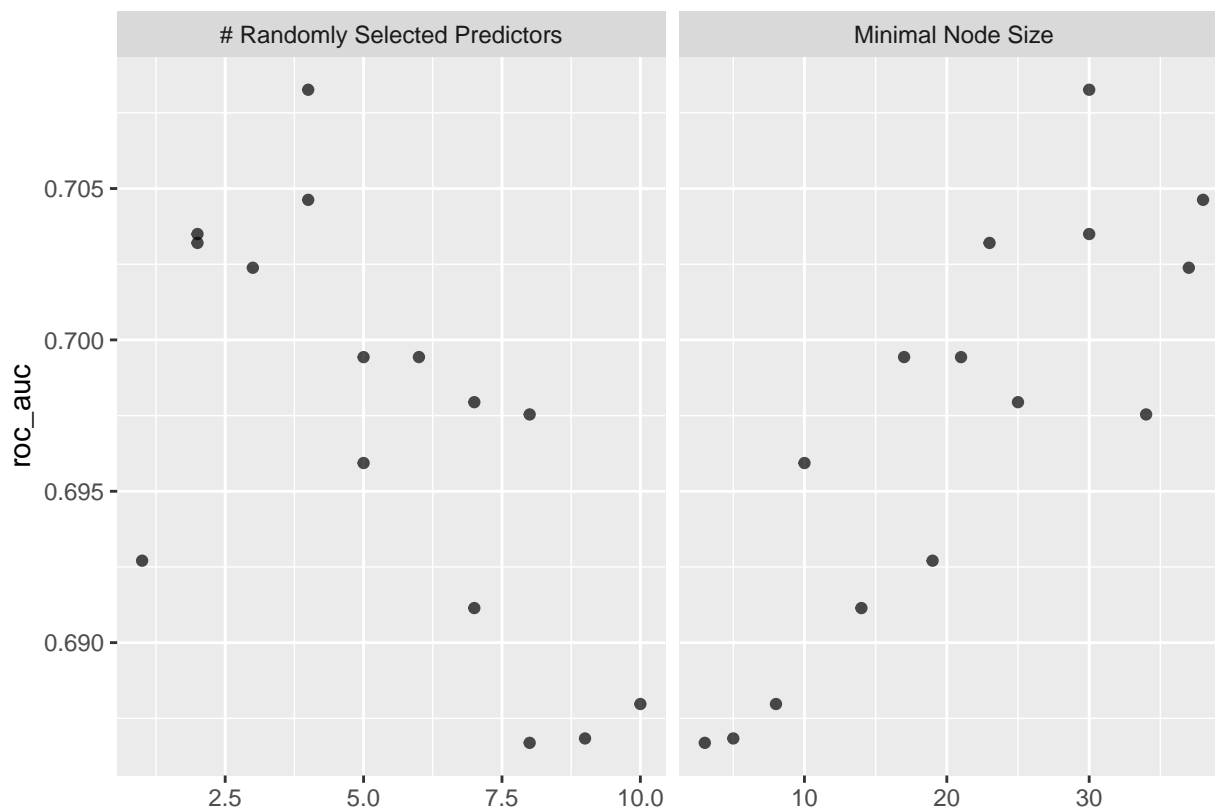
```





# Random Forest

```
rf_recipe <-  
  recipe(formula = sprintf("%s ~ .", outcome_column) %>% as.formula, data = df_train) %>%  
  step_nominal(all_nominal_predictors()) %>%  
  step_unknown(all_nominal_predictors()) %>%  
  step_other(all_nominal_predictors(), threshold = 0.05, other=".merged") %>%  
  step_dummy(all_nominal_predictors(), one_hot = TRUE) %>%  
  step_zv(all_predictors()) %>%  
  step_impute_mean(all_numeric_predictors())  
  
rf_spec <-  
  rand_forest(mtry = tune(),  
              trees = 100,  
              min_n = tune()) %>%  
  set_mode("classification") %>%  
  set_engine("ranger")  
  
rf_grid <- grid_latin_hypercube(mtry(range = c(1, 10)),  
                                min_n(),  
                                size = grid_size)  
  
rf_workflow <-  
  workflow() %>%  
  add_recipe(rf_recipe) %>%  
  add_model(rf_spec)  
  
rf_tune <-  
  rf_workflow %>%  
  tune_grid(resamples = df_folds,  
            grid = rf_grid)  
  
rf_tune %>%  
  collect_metrics()  
  
autoplot(rf_tune, metric = "roc_auc")
```



```
rf_tune %>%
  show_best("roc_auc")

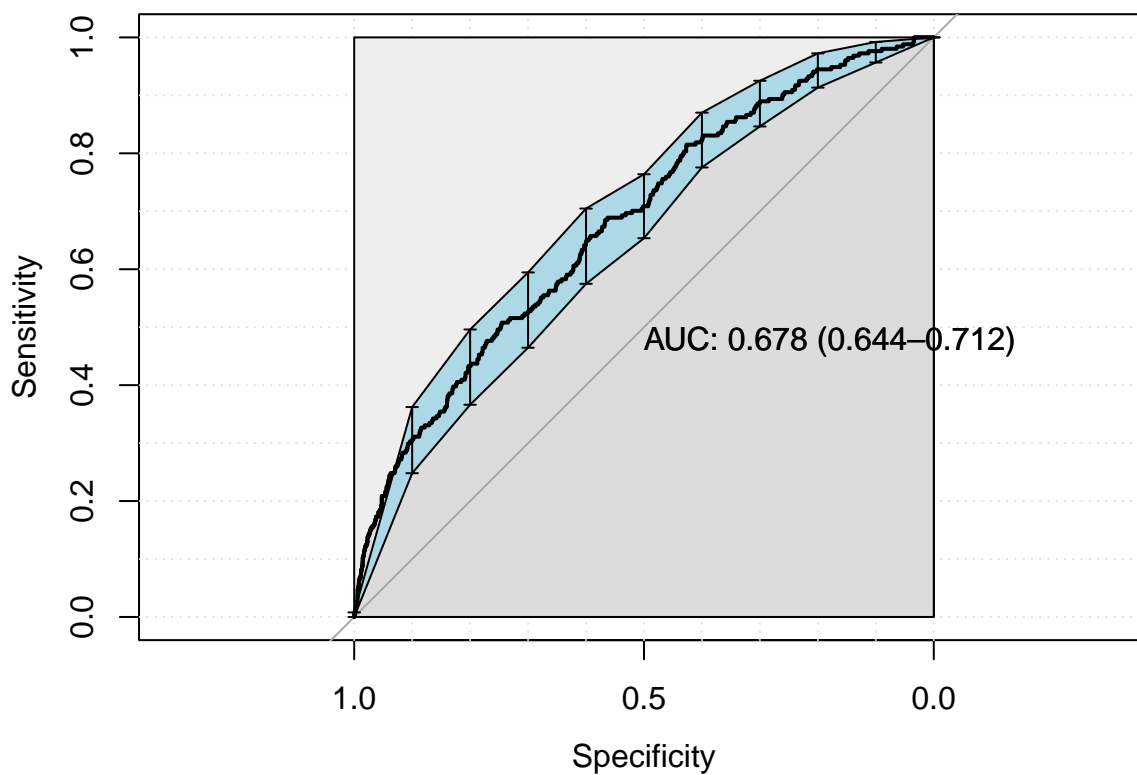
best_rf <- rf_tune %>%
  select_best("roc_auc")

final_rf_workflow <-
  rf_workflow %>%
  finalize_workflow(best_rf)

last_rf_fit <-
  final_rf_workflow %>%
  last_fit(df_split)

final_rf_fit <- extract_workflow(last_rf_fit)

rf_auc <- validation(final_rf_fit, df_test)
```



1.566

Minutes to run:

## KNN

```
# knn_recipe <-
#   recipe(formula = sprintf("%s ~ .", outcome_column) %>% as.formula, data = df_train) %>%
#   step_novel(all_nominal_predictors()) %>%
#   step_unknown(all_nominal_predictors()) %>%
#   step_other(all_nominal_predictors(), threshold = 0.05, other=".merged") %>%
#   step_dummy(all_nominal_predictors(), one_hot = TRUE) %>%
#   step_zv(all_predictors()) %>%
#   step_impute_mean(all_numeric_predictors())
#
# knn_spec <-
#   nearest_neighbor(neighbors = tune(),
#                     weight_func = tune(),
#                     dist_power = tune()) %>%
#   set_mode("classification") %>%
#   set_engine("kknn")
#
# knn_grid <- grid_latin_hypercube(neighbors(),
#                                   weight_func(),
#                                   dist_power(),
#                                   size = 5)
#
# knn_workflow <-
#   workflow() %>%
#   add_recipe(knn_recipe) %>%
#   add_model(knn_spec)
#
# knn_tune <-
#   knn_workflow %>%
#   tune_grid(resamples = df_folds,
```

```

#           grid = knn_grid)
#
# knn_tune %>%
#   collect_metrics()
#
# autoplot(knn_tune, metric = "roc_auc")
#
# knn_tune %>%
#   show_best("roc_auc")
#
# best_knn <- knn_tune %>%
#   select_best("roc_auc")
#
# final_knn_workflow <-
#   knn_workflow %>%
#   finalize_workflow(best_knn)
#
# last_knn_fit <-
#   final_knn_workflow %>%
#   last_fit(df_split)
#
# final_knn_fit <- extract_workflow(last_knn_fit)
#
# knn_auc = validation(final_knn_fit, df_test)

```

Minutes to run: 0

## SVM

```

# svm_recipe <-
#   recipe(formula = sprintf("%s ~ .", outcome_column) %>% as.formula, data = df_train) %>%
#   step_nominal(all_nominal_predictors()) %>%
#   step_unknown(all_nominal_predictors()) %>%
#   step_other(all_nominal_predictors(), threshold = 0.05, other=".merged") %>%
#   step_dummy(all_nominal_predictors(), one_hot = TRUE) %>%
#   step_zv(all_predictors()) %>%
#   step_impute_mean(all_numeric_predictors())
#
# svm_spec <-
#   svm_rbf(cost = tune(), rbf_sigma = tune()) %>%
#   set_mode("classification") %>%
#   set_engine("kernlab")
#
# svm_grid <- grid_latin_hypercube(cost(),
#                                   rbf_sigma(),
#                                   size = grid_size)
#
# svm_workflow <-
#   workflow() %>%
#   add_recipe(svm_recipe) %>%
#   add_model(svm_spec)
#
# svm_tune <-
#   svm_workflow %>%
#   tune_grid(resamples = df_folds,
#             grid = 5)
#
# svm_tune %>%
#   collect_metrics()
#

```

```

# autoplot(sum_tune, metric = "roc_auc")
#
# sum_tune %>%
#   show_best("roc_auc")
#
# best_sum <- sum_tune %>%
#   select_best("roc_auc")
#
# final_sum_workflow <-
#   sum_workflow %>%
#   finalize_workflow(best_sum)
#
# last_sum_fit <-
#   final_sum_workflow %>%
#   last_fit(df_split)
#
# final_sum_fit <- extract_workflow(last_sum_fit)
#
# sum_auc = validation(final_sum_fit, df_test)

```

Minutes to run: 0

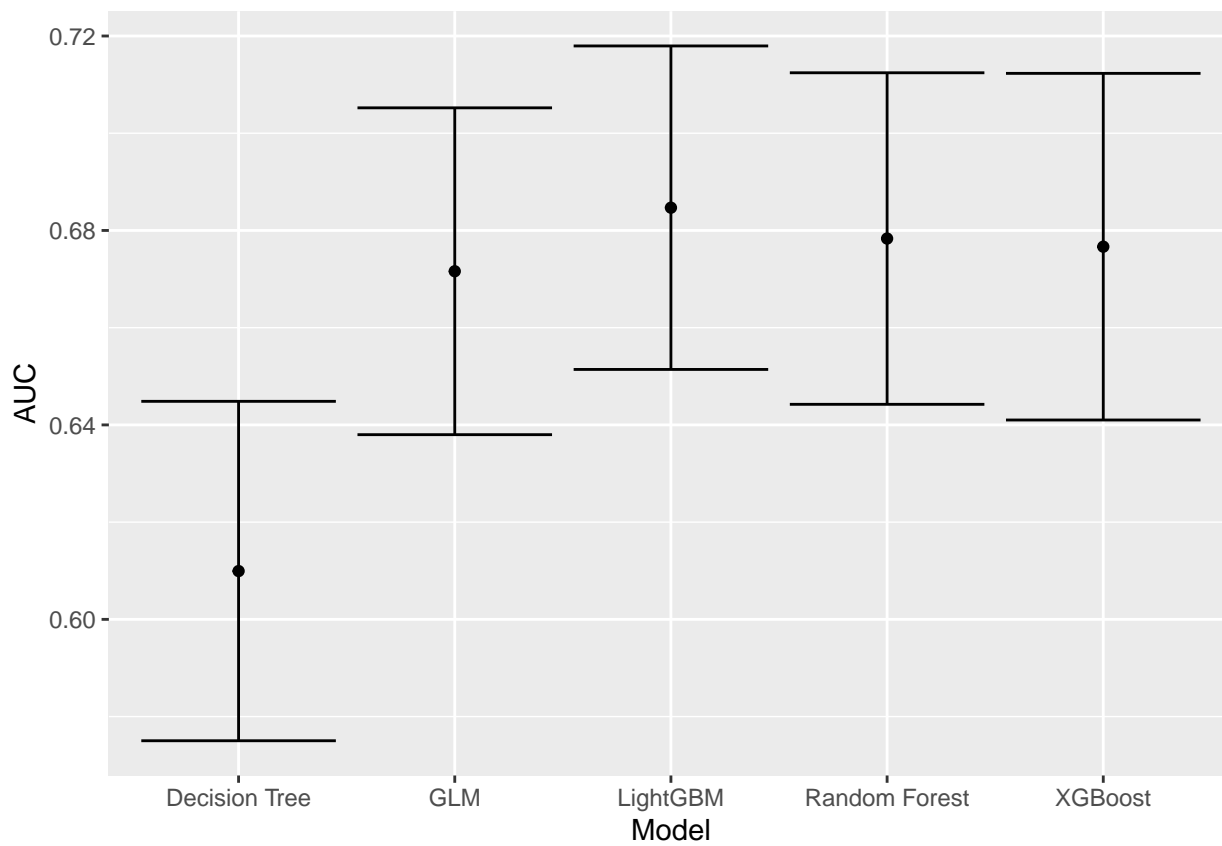
## Models Comparison

```

df_auc <- tibble::tribble(
  ~Model, ~`AUC`, ~`Lower Limit`, ~`Upper Limit`,
  'XGBoost', as.numeric(xgboost_auc$auc), xgboost_auc$ci[1], xgboost_auc$ci[3],
  'LightGBM', as.numeric(lightgbm_auc$auc), lightgbm_auc$ci[1], lightgbm_auc$ci[3],
  'GLM', as.numeric(glm_auc$auc), glm_auc$ci[1], glm_auc$ci[3],
  'Decision Tree', as.numeric(tree_auc$auc), tree_auc$ci[1], tree_auc$ci[3],
  'Random Forest', as.numeric(rf_auc$auc), rf_auc$ci[1], rf_auc$ci[3]
) %>%
  mutate(Target = outcome_column)

df_auc %>%
  ggplot(aes(x = Model, y = AUC, ymin = `Lower Limit`, ymax = `Upper Limit`)) +
    geom_point() +
    geom_errorbar()

```



```
saveRDS(df_auc, sprintf("./auxiliar/model_selection/performance/%s.RData", outcome_column))
```

Minutes to run: 0.009