

Final Project

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Introduction

Today, diabetes is one of the major chronic diseases in the world. Center of Disease Control and Prevention (CDC) estimates that 37.3 million Americans (approximately 10 percent of total population) have diabetes; however, about 1 in 5 people with diabetes do not recognize they actually have it. One reason of their unawareness is that there are few subjective symptoms in the early stages of diabetes. Also, because of this traits of diabetes, it is not uncommon for the disease to be discovered only after it has progressed.

The purpose of this project is to predict the history of diabetes by using limited set of information. If the risk of developing diabetes can be accurately predicted based on information that is easily available through administrative records or simple questionnaires (such as demographic information, height, and weight), it would be possible to encourage only high-risk population to undergo physical examination, which could improve the national healthcare budget and population health at the same time.

Data Set

I use 2021 (latest) version of Behavioral Risk Factor Surveillance System (BRFSS) dataset, which is the nation's representative telephone surveys that collect state data about their health-related risk behaviors, chronic health conditions, and use of preventive services. BRFSS collects data from all 50 states as well as the District of Columbia and three U.S. territories. Starting from 1980, the rough sample size is over 400,000 per year, which I believe is a sufficient number to predict some phenomena using the machine learning method. Although BRFSS contains an abundant number of variables especially on health habit (e.g. smoking, drinking, fruits intake, etc.), I will not utilize them. There are two main reasons. First, we have to keep in mind that these variables can be significantly affected by the diagnosis of diabetes. Hence, it might not be appropriate to predict the history of diabetes diagnosis, which makes me use the set of variables which is less likely to be affected by the diagnosis. Second, as the main objective of this study is to classify the diabetes patients as precisely as possible using a limited information that is not costly to gather. In this sense, I believe that the exclusion of health behavior variables is reasonable. In the next section, I briefly explain about the choice of predictor and cleaning procedure.

Preliminary steps

Data Cleaning / List of Variables Data cleaning is executed by the R script named `data_processing.R`. Please refer to this file for the detailed steps. Here, I give a succinct explanation about the steps I took.

1. Import the raw data. Because the format of raw data is `.xpt` (SAS XPORT File), I used `foreign::read.xport` package. * Because the file size of the raw data is too large to upload on github repository, the raw data is not available at my github repository page. It is available at https://www.cdc.gov/brfss/annual_data/annual_2021.html
2. Select and re-code the variables. If the answer is 9 or 99, it means missing. Hence, I replaced them with NA. Also, I replace 7 or 77 (refuse to answer) with NA.
3. Drop the sample in Puerto Rico (Focusing just on 50 states + DC).
4. As `age` variable is truncated at 80 (coded as 80 if older than 80), I dropped these truncated sample in order to avoid the measurement error in predictor.

5. Save the processed data as `brfss_final.csv`.

List of all the variables used in this project is described in `BRFSS_final_Codebook.pdf` file.

- `state`: State FIPS Code (Including Washington DC, excluding Guam, Puerto Rico, and Virgin Islands)
- `sex`: Sex of Respondents
- `metro_status`: Metropolitan Status
- `urban_status`: Urban/Rural Status
- `race`: Race of Respondents
- `marital`: Marital Status
- `education`: Education Level
- `home_rent_own`: Own or Rent Home
- `veteran`: Veteran Status
- `employ`: Employment Status
- `num_children`: Number of Total Children Younger than 18 Years Old (continuous)
- `income_gr`: Income Level
- `age`: Age of Respondents (continuous)
- `ins_dummy`: Dummy for Having Any Health Insurance
- `height_meter`: Height in meter (continuous)
- `weight_kg`: Weight in kilogram (continuous)
- `bmi`: Body Mass Index (BMI) (continuous)
- `diabete`: History of Diabetes Diagnosis

Loading packages First, I load the necessary packages using `library` function.

```
library(tidyverse)
library(tidymodels)
library(corrplot)
library(ggplot2)
library(MASS)
library(discrim)
library(ranger) #random forest
library(xgboost)
library(vip)
```

Import csv file (processed using `data_processing.R` script) as a tibble:

```
set.seed(1234)
brfss <- read_csv("cleaned_data/brfss_final.csv")

# Drop sample missing in any variables.
brfss <- brfss %>%
  drop_na()

brfss <- brfss %>% sample_n(size=10000)
```

Here, I dropped observations if any of variables are missing. Also, to reduce the computation time, I decided to randomly pick up 10000 samples. *#### Data split*

Split the data into training and testing set with stratifying by outcome.

```
set.seed(12)
diabete_split <- initial_split(brfss,
                              prop = 0.75,
                              strata = diabete)
diabete_train <- training(diabete_split)
diabete_test <- testing(diabete_split)
```

```
#Make sure the dimension of dataset is correct.  
dim(diabete_train)
```

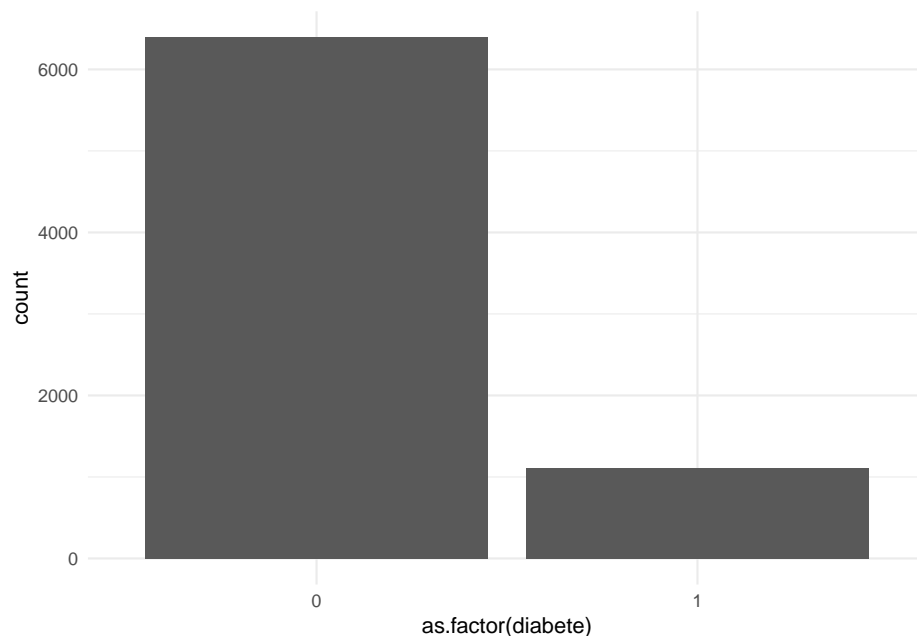
```
## [1] 7500  21
```

```
dim(diabete_test)
```

```
## [1] 2500  21
```

Descriptive statistics The distribution of outcome variables by ggplot. We can see that the fraction of people with diabetes history is approximately 14.8 percent, which is slightly higher than the estimate by CDC, but remember that I coded Yes for pre-diabetes or borderline people.

```
hist_diabete <- diabete_train %>%  
  ggplot(aes(as.factor(diabete))) +  
  geom_bar() +  
  theme_minimal()  
plot(hist_diabete)
```



```
mean_outcome <- diabete_train %>%  
  summarise(frac_diabete = mean(as.numeric(diabete)))
```

```
mean_outcome
```

```
## # A tibble: 1 x 1  
##   frac_diabete  
##         <dbl>  
## 1         0.148
```

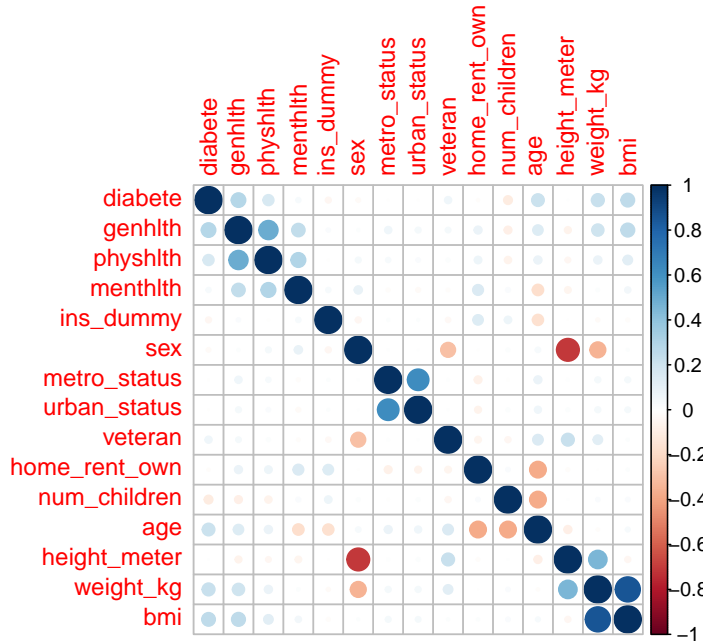
Next, I check the correlation between outcome (i.e. diabetes) and predictors: I can see that general health description, age weight, and BMI may be a good predictor because the correlation seems to be more significant than others.

```
diabete_train %>%  
  dplyr::select(diabete, genhlth, physhlth,
```

```

    menthlth, ins_dummy, sex,
    metro_status, urban_status,
    veteran, home_rent_own,
    num_children, age, height_meter,
    weight_kg, bmi) %>%
cor(use = "complete.obs") %>%
corrplot(method = "circle")

```



For the convenience in the later analysis, I change the format of categorical variables from numeric to factor:

```

# Define categorical variables as factor
## Training data
diabetes_train <- diabetes_train %>%
  mutate(state = as.factor(state)) %>%
  mutate(genhlth = as.factor(genhlth)) %>%
  mutate(sex = as.factor(sex)) %>%
  mutate(metro_status = as.factor(metro_status)) %>%
  mutate(urban_status = as.factor(urban_status)) %>%
  mutate(race = as.factor(race)) %>%
  mutate(marital = as.factor(marital)) %>%
  mutate(education = as.factor(education)) %>%
  mutate(home_rent_own = as.factor(home_rent_own)) %>%
  mutate(veteran = as.factor(veteran)) %>%
  mutate(employ = as.factor(employ)) %>%
  mutate(income_gr = as.factor(income_gr)) %>%
  mutate(ins_dummy = as.factor(ins_dummy)) %>%
  mutate(diabetes = as.factor(diabetes))

## Test data
diabetes_test <- diabetes_test %>%
  mutate(state = as.factor(state)) %>%
  mutate(genhlth = as.factor(genhlth)) %>%
  mutate(sex = as.factor(sex)) %>%

```

```

mutate(metro_status = as.factor(metro_status)) %>%
mutate(urban_status = as.factor(urban_status)) %>%
mutate(race = as.factor(race)) %>%
mutate(marital = as.factor(marital)) %>%
mutate(education = as.factor(education)) %>%
mutate(home_rent_own = as.factor(home_rent_own)) %>%
mutate(veteran = as.factor(veteran)) %>%
mutate(employ = as.factor(employ)) %>%
mutate(income_gr = as.factor(income_gr)) %>%
mutate(ins_dummy = as.factor(ins_dummy)) %>%
mutate(diabete = as.factor(diabete))

```

I apply 5-folds cross validation to avoid the possibility of overfitting to the training dataset:

```
diabete_folds <- vfold_cv(diabete_train, v = 5, strata = diabete)
```

Recipe I convert all categorical predictors to dummy variables. Also, I scale and center all the predictors.

```

diabete_recipe<-recipe(diabete ~ ., data = diabete_train) %>%
  step_dummy(all_nominal_predictors()) %>%
  step_scale(all_predictors()) %>%
  step_center(all_predictors())

```

Build models

In this project, I try the following four models:

- Logistic regression
- LDA
- Random Forest
- Boosted Trees
-

Logistic regression First model I am going to apply is simple Logistic regression. Here, I do not use regularization method. To assess the prediction performance for training set, I use five-folds cross validation.

```

## Logistic regression
# Engine
log_reg <- logistic_reg() %>%
  set_engine("glm") %>%
  set_mode("classification")

# Workflow
log_wkflow <- workflow() %>%
  add_model(log_reg) %>%
  add_recipe(diabete_recipe)

# tuning
tune_log <- tune_grid(object = log_wkflow, resamples = diabete_folds)

save(tune_log, file = "model_fit/logistic_tune.rda")

```

```

## LDA
# Engine

```

```
lda <- discrim_linear() %>%
  set_engine("MASS") %>%
  set_mode("classification")
# Workflow
lda_wkflow <- workflow() %>%
  add_model(lda) %>%
  add_recipe(diabete_recipe)
```

```
# Tuning
tune_lda <- tune_grid(object = lda_wkflow, resamples = diabete_folds)

save(tune_lda, file = "model_fit/lda_tune.rda")
```

Linear discriminant analysis (LDA)

```
rf_model <-
  rand_forest(
    min_n = tune(),
    mtry = tune(),
    trees = tune(),
    mode = "classification") %>%
  set_engine("ranger", importance = "impurity")

rf_workflow <- workflow() %>%
  add_model(rf_model) %>%
  add_recipe(diabete_recipe)
```

Random forest Next, I set up the grids of tuning parameters. Note that because the total number of predictors is 20, mtry should be 20 at most.

```
rf_params <- parameters(rf_model) %>%
  update(mtry = mtry(range= c(2, 20)),
    trees = trees(range=c(1,1000)),
    min_n = min_n(range=c(1,40)))

# Define grid
rf_grid <- grid_regular(rf_params, levels = 4)
```

Then, I execute random forest model and search the optimal tuning parameter. As this procedure takes tons of times, I set `eval = FALSE` so that I do not need run again in knitting the report.

```
rf_tune <- rf_workflow %>%
  tune_grid(resamples = diabete_folds,
    grid = rf_grid)

save(rf_tune, rf_workflow, file = "model_fit/randomforest_tune.rda")
```

Boosted trees First, I set up the models, workflows, and grids in the similar way as I did for random forest model.

```
bt_model <- boost_tree(
  mode = "classification",
  min_n = tune(),
```

```

mtry = tune(),
learn_rate = tune(),
trees = tune()) %>%
set_engine("xgboost")

bt_workflow <- workflow() %>%
  add_model(bt_model) %>%
  add_recipe(diabetes_recipe)

bt_params <- parameters(bt_model) %>%
  update(mtry = mtry(range = c(2, 20)),
         learn_rate = learn_rate(range = c(-5, 0.2)),
         min_n = min_n(range = c(1, 40)),
         trees = trees(range = c(1, 1000)))

# define grid
bt_grid <- grid_regular(bt_params, levels = 4)

bt_tune <- bt_workflow %>%
  tune_grid(
    resamples = diabetes_folds,
    grid = bt_grid
  )

# save results
save(bt_tune, bt_workflow, file = "model_fit/bt_tune.rda")

```

Model Analysis

- Logistic regression

```

load(file = "model_fit/logistic_tune.rda")
collect_metrics(tune_log)

```

```

## # A tibble: 2 x 6
##   .metric .estimator mean      n std_err .config
##   <chr>   <chr>      <dbl> <int>  <dbl> <chr>
## 1 accuracy binary    0.854     5 0.00263 Preprocessor1_Model1
## 2 roc_auc  binary    0.799     5 0.0107  Preprocessor1_Model1

```

- LDA

```

load(file = "model_fit/lda_tune.rda")
collect_metrics(tune_lda)

```

```

## # A tibble: 2 x 6
##   .metric .estimator mean      n std_err .config
##   <chr>   <chr>      <dbl> <int>  <dbl> <chr>
## 1 accuracy binary    0.852     5 0.00375 Preprocessor1_Model1
## 2 roc_auc  binary    0.797     5 0.00914 Preprocessor1_Model1

```

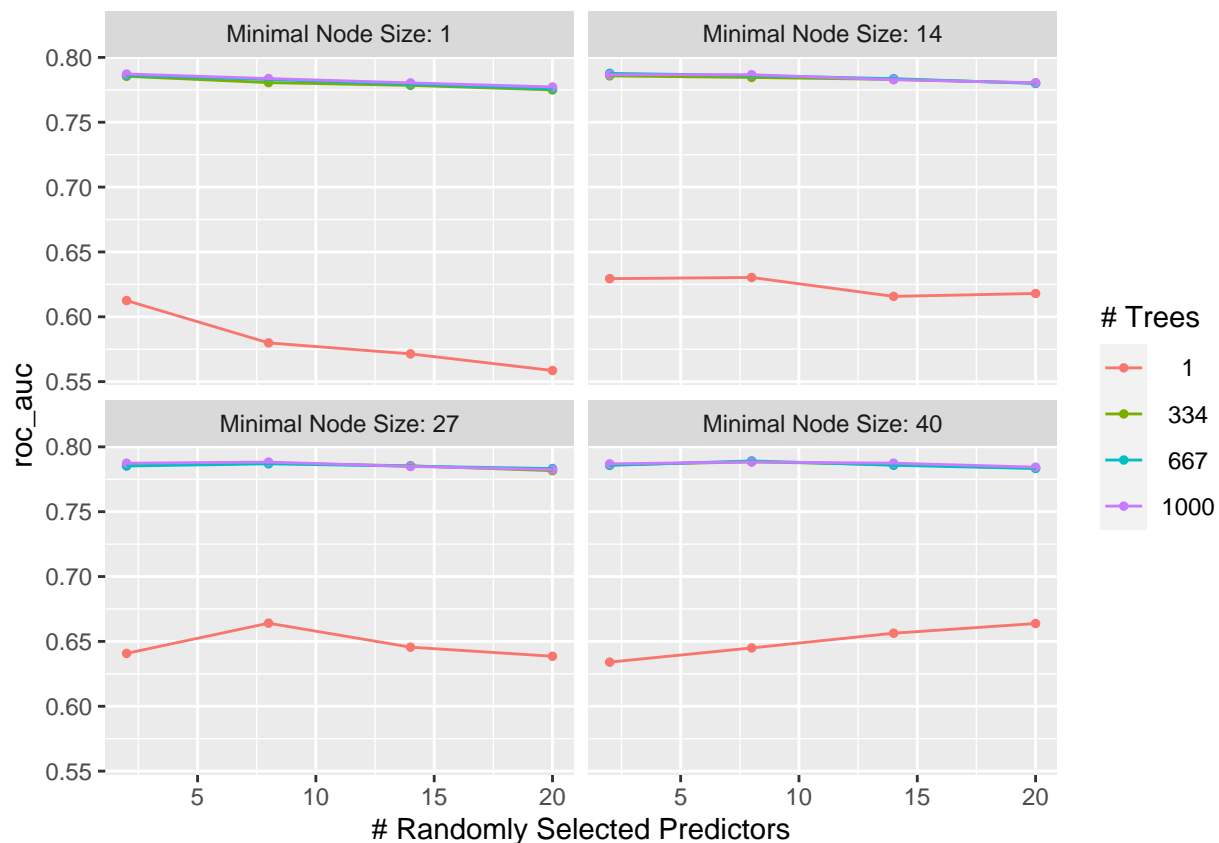
- Random forest

```

load(file = "model_fit/randomforest_tune.rda")

autoplot(rf_tune, metric = "roc_auc")

```

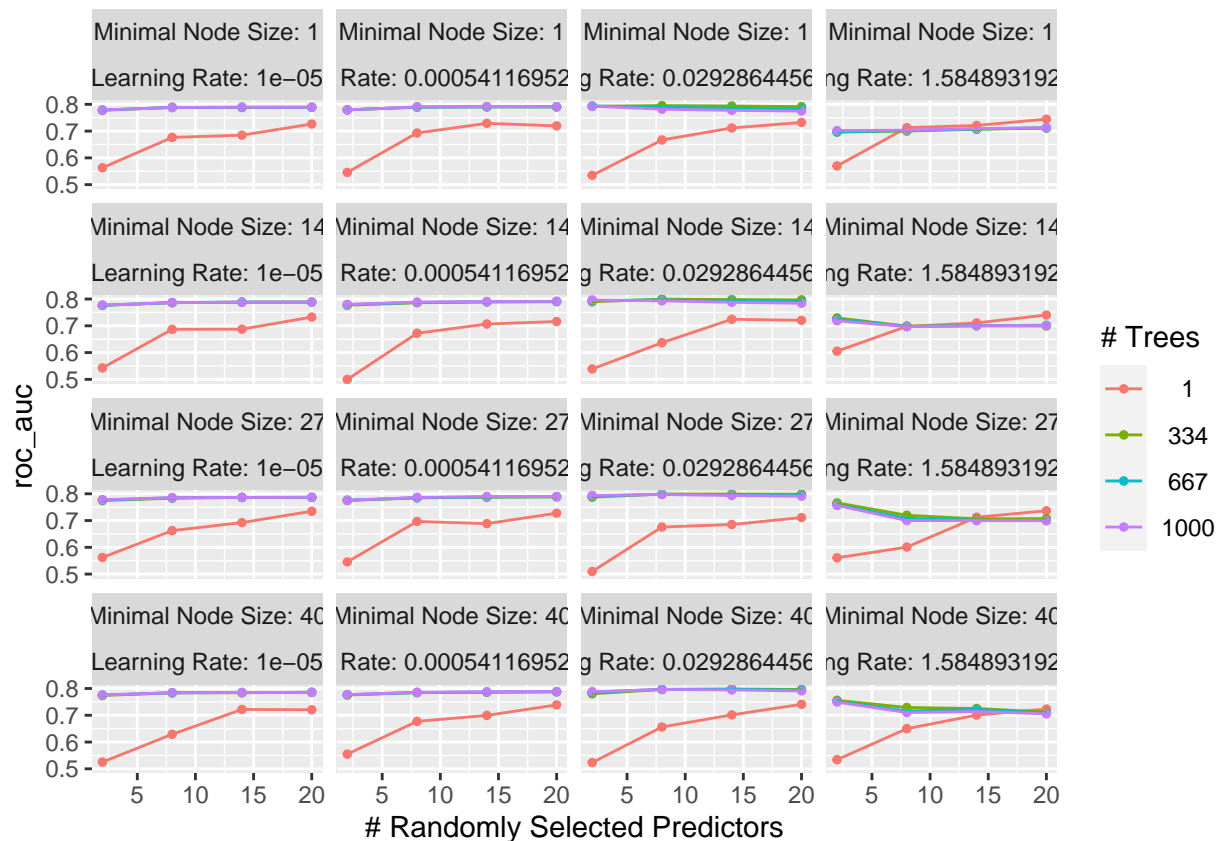


```
show_best(rf_tune, metric = "roc_auc") %>%
  dplyr::select(-.estimator, -.config)
```

```
## # A tibble: 5 x 7
##   mtry trees min_n .metric mean     n std_err
##   <int> <int> <int> <chr>  <dbl> <int>  <dbl>
## 1     8   667   40 roc_auc 0.789     5 0.00977
## 2     8   334   40 roc_auc 0.788     5 0.0101
## 3     8  1000   40 roc_auc 0.788     5 0.00974
## 4     8  1000   27 roc_auc 0.788     5 0.00996
## 5     2   667   14 roc_auc 0.788     5 0.00969
```

- Boosted tree

```
load(file = "model_fit/bt_tune.rda")
autoplot(bt_tune, metric = "roc_auc")
```

```
show_best(bt_tune, metric = "roc_auc") %>% dplyr::select(-.estimator, -.config)
```

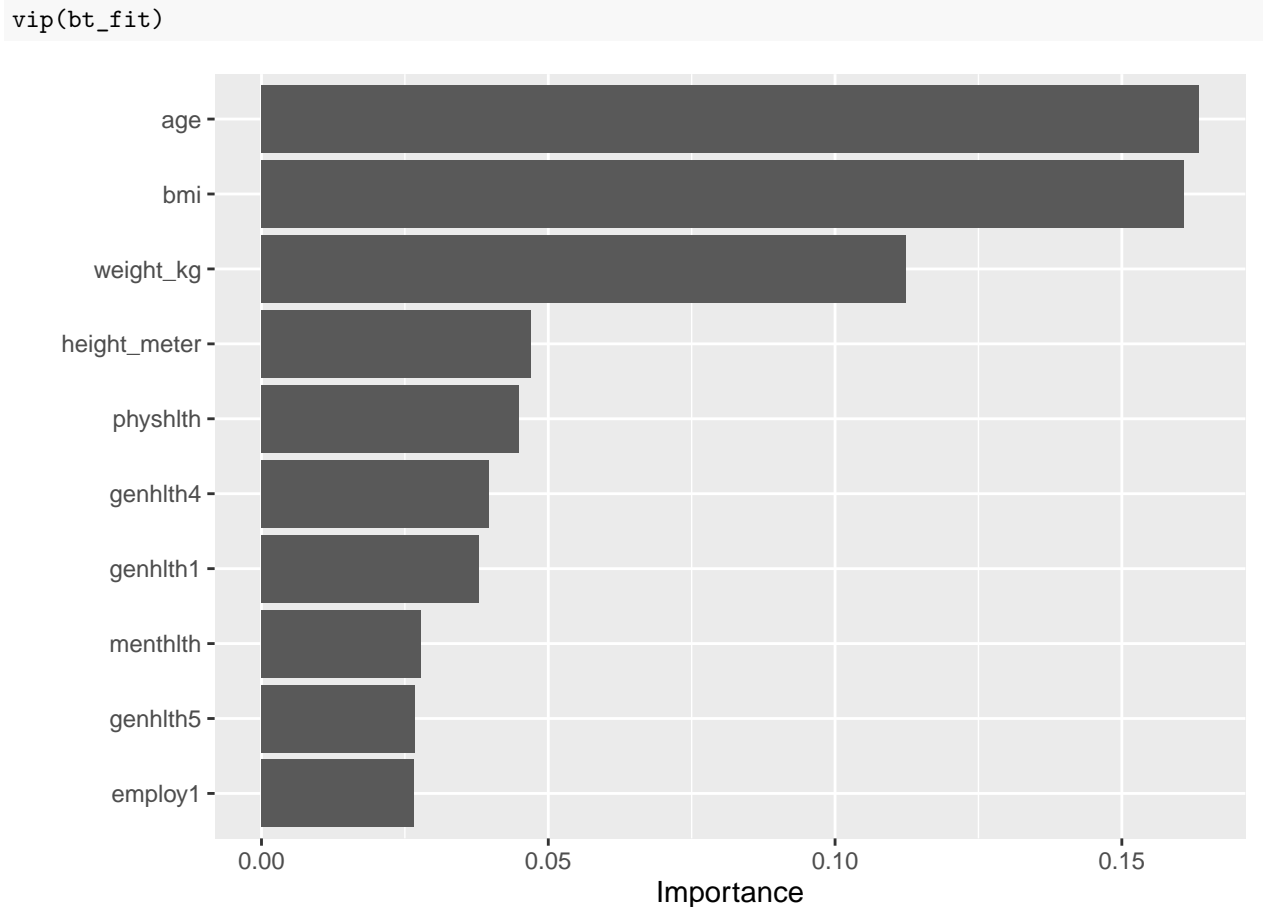
```
## # A tibble: 5 x 8
##   mtry trees min_n learn_rate .metric mean      n std_err
##   <int> <int> <int>      <dbl> <chr>  <dbl> <int>  <dbl>
## 1     8   334   14      0.0293 roc_auc 0.800     5 0.00974
## 2    14   334   27      0.0293 roc_auc 0.799     5 0.00973
## 3     8   334   27      0.0293 roc_auc 0.799     5 0.00910
## 4    20   334   27      0.0293 roc_auc 0.798     5 0.00991
## 5     8   667   27      0.0293 roc_auc 0.798     5 0.00981
```

Combining all the performance results, I conclude that **Boosted tree model** is the best model, and random forest is almost as precise as logistic regression. In the next section, I apply these two models to test data and measure the prediction performance (by AUC).

```
bt_spec <- boost_tree(mtry = 8, trees = 334, min_n = 14) %>%
  set_engine("xgboost", importance = TRUE) %>%
  set_mode("classification")

bt_fit <- fit(bt_spec, diabetes ~ .,
              data = diabetes_train)
```

```
## [17:49:18] WARNING: amalgamation/./src/learner.cc:627:
## Parameters: { "importance" } might not be used.
##
## This could be a false alarm, with some parameters getting used by language bindings but
## then being mistakenly passed down to XGBoost core, or some parameter actually being used
## but getting flagged wrongly here. Please open an issue if you find any such cases.
```



The figure implies that age, weight, and BMI are the important predictors of diabetes history among all. Here, one important finding is that variables like `genhlth`, `physhlth` and `menthlth` are not as important as the above variables. This result suggests that nudging people from the information such as weight and age (which are comparatively easier for health sector to get) will be effective.

Applying the Best Model(s) to the Test Set

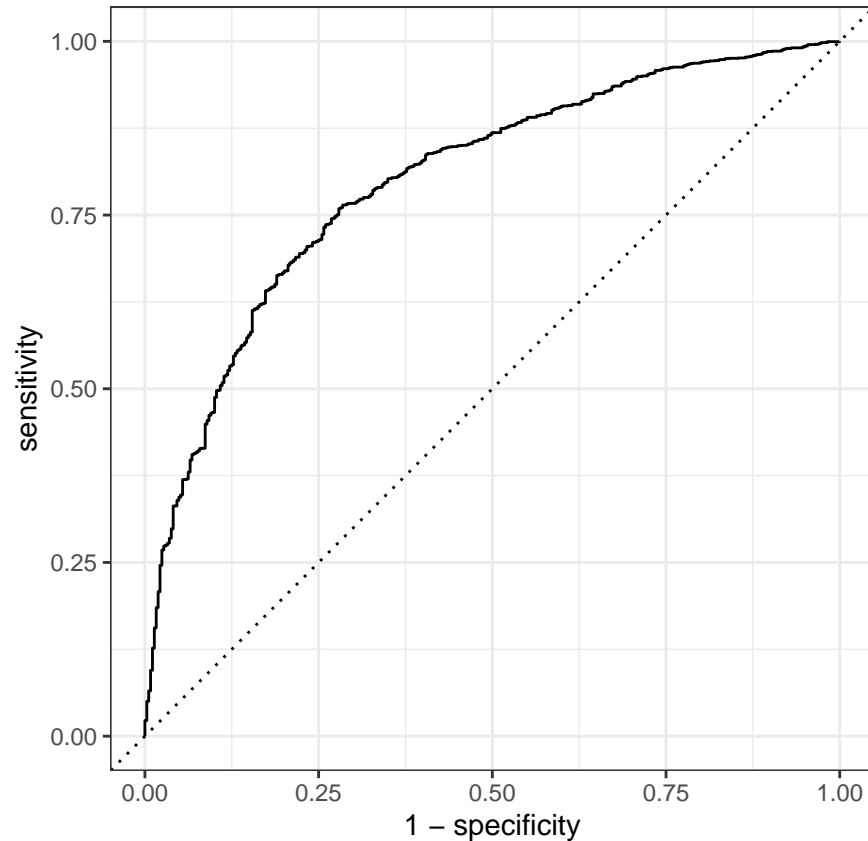
Now, I apply boosted tree (with best tuning parameters) on all the testing data:

```
bt_workflow_tuned <- bt_workflow %>%
  finalize_workflow(select_best(bt_tune, metric = "roc_auc"))

bt_results_on_train <- fit(bt_workflow_tuned, diabete_train)
```

Finally, I see the performance on testing data. Here, I provide the ROC curve and the AUC:

```
augment(bt_results_on_train,
  new_data = diabete_test) %>%
  roc_curve(truth = diabete,
    estimate = c(.pred_0)) %>%
  autoplot()
```



```
augment(bt_results_on_train,
        new_data = diabete_test) %>%
  roc_auc(truth = diabete,
          estimate = c(.pred_0))
```

```
## # A tibble: 1 x 3
##   .metric .estimator .estimate
##   <chr>   <chr>      <dbl>
## 1 roc_auc binary      0.800
```

Surprisingly, the performance on the test data is almost the same as the performance we saw in 5-fold cross validation. In my understanding, there are two reasons. First, this would be the indication that the 5-fold cross validation effectively avoid the overfitting. Second, the large number of sample in both training and testing dataset achieve the consistency in its performance.

Conclusion

In this short article, I estimate the model to predict the risk of diabetes based on **limited** information which can be easily accessed without experiments or detailed surveys that costs a lot of funds. Surprisingly, I found that the prediction performance based on these limited information is decent: AUC is almost 0.8. Thanks to the large sample size, the performance of my boosted tree model on the test sample was almost as good as that on training dataset.

Diabetes is one of the common disease all over the world; however, on the other hand, it is preventable by taking healthy habit. My results of this project suggest the importance of cooperation between public heath sector (such as department of health in each state) and local hospitals. For instance, if hospitals provide some basic patients' information such as weight or BMI to administrative sectors, the effective intervention (e.g. recommendation of diabetes screening) will be feasible.