Diabetes Risk Prediction

Madibaa

2024-04-02

Introduction

Diabetes is a chronic, metabolic disease characterised by elevated blood sugar levels, which leads over time to damage to the organs[1]. The incidence of diabetes has rapidly risen in association with the global rise in obesity, sedentary lifestyles, consumption of ultra-processed foods, and rapidly ageing populations. It is estimated that there are 537 million individuals living with diabetes as of 2021[2]. As a healthcare researcher, I'm deeply interested in understanding the risk factors associated with diabetes, in hopes of making a small contribution towards humanity's efforts in ridding us of this disease.

About the dataset

This dataset was provided by the National Institute of Diabetes and Digestive and Kidney Diseases. The data are from a population of females of Pima Indian heritage, aged 21 years and above, with 8 medical predictors of diabetes outcome:

- number of times pregnant
- plasma glucose concentration a 2 hours in an oral glucose tolerance test
- diastolic blood pressure readings (mm Hg)
- triceps skinfold thickness (mm)
- 2-Hour serum insulin (mu U/ml)
- body mass index (weight in kg/(height in m)^2)
- diabetes pedigree function (DPF)
- age (years)

To access the dataset or view others attempts to build classification models, visit https://www.kaggle.com/datasets/uciml/pima-indians-diabetes-database/data or https://www.kaggle.com/datasets/mathchi/diabetes-data-set/data

Objective

The aim of this project is to develop train and evaluate several machine learning models and ensembles of models to optimise accuracy and area under the receiver operating characteristic curve (AUC). For this project, we will consider the following models: general linear model (GLM), k-nearest neighbours (KNN), locally estimated scatterplot smoothing (LOESS), recursive partitioning and regression trees (rpart), random forest (RF), extreme gradient boosting (XGB), and naive Bayes (NB).

Let's dive right in!

Methods and Results

Exploratory Analyses

Let us begin by importing the diabetes dataset.

```
# Set the working directory accordingly
setwd("C:/Users/cyc_c/Desktop/Data Science/projects/diabetes_risk_prediction")
diabetes <- read.csv("diabetes.csv")
```

Next, we will load some required packages.

```
library(tidyverse)  # for it's awesomeness
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.2     v readr     2.1.4
## v forcats   1.0.0     v stringr   1.5.0
## v ggplot2   3.4.2     v tibble    3.2.1
## v lubridate 1.9.2     v tidyr     1.3.0
## v purrr     1.0.1
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become error
```

```
library(caret)  # for training our models
```

```
## Loading required package: lattice
##
## Attaching package: 'caret'
##
## The following object is masked from 'package:purrr':
##
##     lift
```

```
library(corrplot)  # for visualising correlations
```

```
## corrplot 0.92 loaded
```

```
library(gam)  # for building a Loess model using the caret package
```

```
## Loading required package: splines
## Loading required package: foreach
##
## Attaching package: 'foreach'
##
## The following objects are masked from 'package:purrr':
##
##     accumulate, when
##
## Loaded gam 1.22-3
```

```
library(rpart)  # for building a classification tree model using the caret package
library(randomForest)  # for building a random forest model using the caret package
```

```
## randomForest 4.7-1.1
## Type rfNews() to see new features/changes/bug fixes.
##
## Attaching package: 'randomForest'
##
## The following object is masked from 'package:dplyr':
##
##     combine
##
## The following object is masked from 'package:ggplot2':
##
##     margin
```

```
library(xgboost)  # for building an extreme gradient boosting model using the caret package
```

```
##
## Attaching package: 'xgboost'
##
## The following object is masked from 'package:dplyr':
##
##     slice
```

```
library(pROC)  # for calculating AUC values
```

```
## Type 'citation("pROC")' for a citation.
##
## Attaching package: 'pROC'
##
## The following objects are masked from 'package:stats':
##
##     cov, smooth, var
```

Let us now conduct some preliminary exploration of the data.

```
head(diabetes)
```

```
##   Pregnancies Glucose BloodPressure SkinThickness Insulin  BMI
## 1           6     148            72            35       0 33.6
## 2           1      85            66            29       0 26.6
## 3           8     183            64             0       0 23.3
## 4           1      89            66            23      94 28.1
## 5           0     137            40            35     168 43.1
## 6           5     116            74             0       0 25.6
##   DiabetesPedigreeFunction Age Outcome
## 1                    0.627  50       1
## 2                    0.351  31       0
## 3                    0.672  32       1
## 4                    0.167  21       0
## 5                    2.288  33       1
## 6                    0.201  30       0
```

```r
dim(diabetes)
```

```
## [1] 768   9
```

```r
str(diabetes)
```

```
## 'data.frame':    768 obs. of  9 variables:
##  $ Pregnancies             : int  6 1 8 1 0 5 3 10 2 8 ...
##  $ Glucose                 : int  148 85 183 89 137 116 78 115 197 125 ...
##  $ BloodPressure           : int  72 66 64 66 40 74 50 0 70 96 ...
##  $ SkinThickness           : int  35 29 0 23 35 0 32 0 45 0 ...
##  $ Insulin                 : int  0 0 0 94 168 0 88 0 543 0 ...
##  $ BMI                     : num  33.6 26.6 23.3 28.1 43.1 25.6 31 35.3 30.5 0 ...
##  $ DiabetesPedigreeFunction: num  0.627 0.351 0.672 0.167 2.288 ...
##  $ Age                     : int  50 31 32 21 33 30 26 29 53 54 ...
##  $ Outcome                 : int  1 0 1 0 1 0 1 0 1 1 ...
```

```r
summary(diabetes)
```

```
##   Pregnancies        Glucose      BloodPressure    SkinThickness
##  Min.   : 0.000   Min.   :  0.0   Min.   :  0.00   Min.   : 0.00
##  1st Qu.: 1.000   1st Qu.: 99.0   1st Qu.: 62.00   1st Qu.: 0.00
##  Median : 3.000   Median :117.0   Median : 72.00   Median :23.00
##  Mean   : 3.845   Mean   :120.9   Mean   : 69.11   Mean   :20.54
##  3rd Qu.: 6.000   3rd Qu.:140.2   3rd Qu.: 80.00   3rd Qu.:32.00
##  Max.   :17.000   Max.   :199.0   Max.   :122.00   Max.   :99.00
##     Insulin           BMI        DiabetesPedigreeFunction      Age
##  Min.   :  0.0   Min.   : 0.00   Min.   :0.0780           Min.   :21.00
##  1st Qu.:  0.0   1st Qu.:27.30   1st Qu.:0.2437           1st Qu.:24.00
##  Median : 30.5   Median :32.00   Median :0.3725           Median :29.00
##  Mean   : 79.8   Mean   :31.99   Mean   :0.4719           Mean   :33.24
##  3rd Qu.:127.2   3rd Qu.:36.60   3rd Qu.:0.6262           3rd Qu.:41.00
##  Max.   :846.0   Max.   :67.10   Max.   :2.4200           Max.   :81.00
##     Outcome
##  Min.   :0.000
##  1st Qu.:0.000
##  Median :0.000
##  Mean   :0.349
##  3rd Qu.:1.000
##  Max.   :1.000
```

We see that the dataset comprises 768 observations of 9 variables, including 8 predictors and an Outcome variable. BMI and DiabetesPedigreeFunction are numerics, while the rest of the variables are integers.

We can also note that certain clinical values are off - there are values of 0 for glucose, blood pressure, skin thickness, insulin, and BMI which is impossible. The possible explanation is that the 0s in these cases represent missing values. We can confirm this with some visual analyses shortly.

Let us check if there are any missing values and duplicates in the data.

```r
any(is.na(diabetes))  # to check for missing values
```

```
## [1] FALSE
```

```
diabetes[duplicated(diabetes), ]  # to check for duplicates
```

```
## [1] Pregnancies              Glucose                  BloodPressure
## [4] SkinThickness            Insulin                  BMI
## [7] DiabetesPedigreeFunction Age                      Outcome
## <0 rows> (or 0-length row.names)
```

The data looks good, with no missing values or duplicates.

Let us look at the overall prevelance of diabetes in this population.

```
mean(diabetes$Outcome)
```

```
## [1] 0.3489583
```

We can see that 34.9%, or slightly over a third of this population present with diabetes. It is time to move on to some visual analyses.

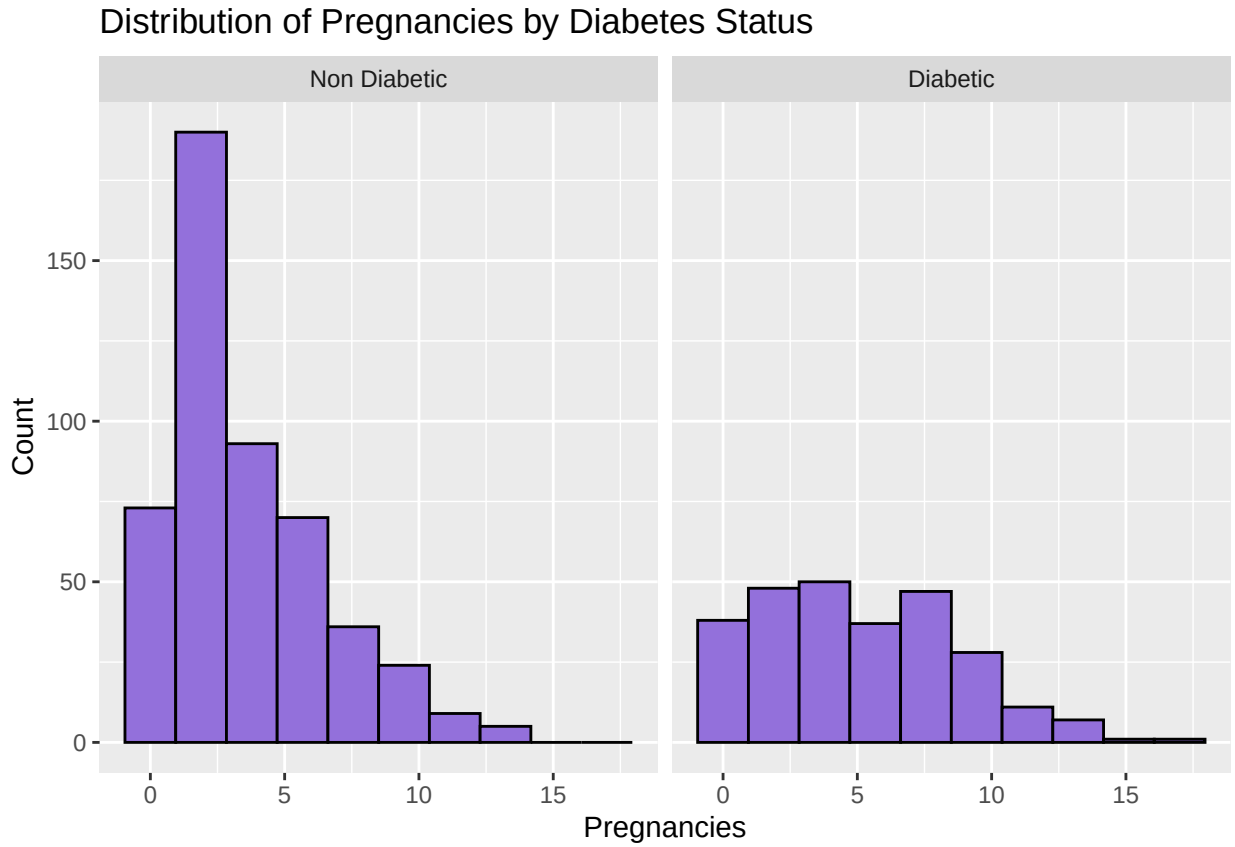
Visual Analyses

We are going to plot all the variables for a quick visual inspection First, let's convert Outcome variable to factor with labels for plotting.

```
diabetes_plot <- diabetes %>%
    mutate(Outcome = factor(Outcome, labels = c("Non Diabetic", "Diabetic")))
```

Let us plot the number of pregnancies by diabetes status.

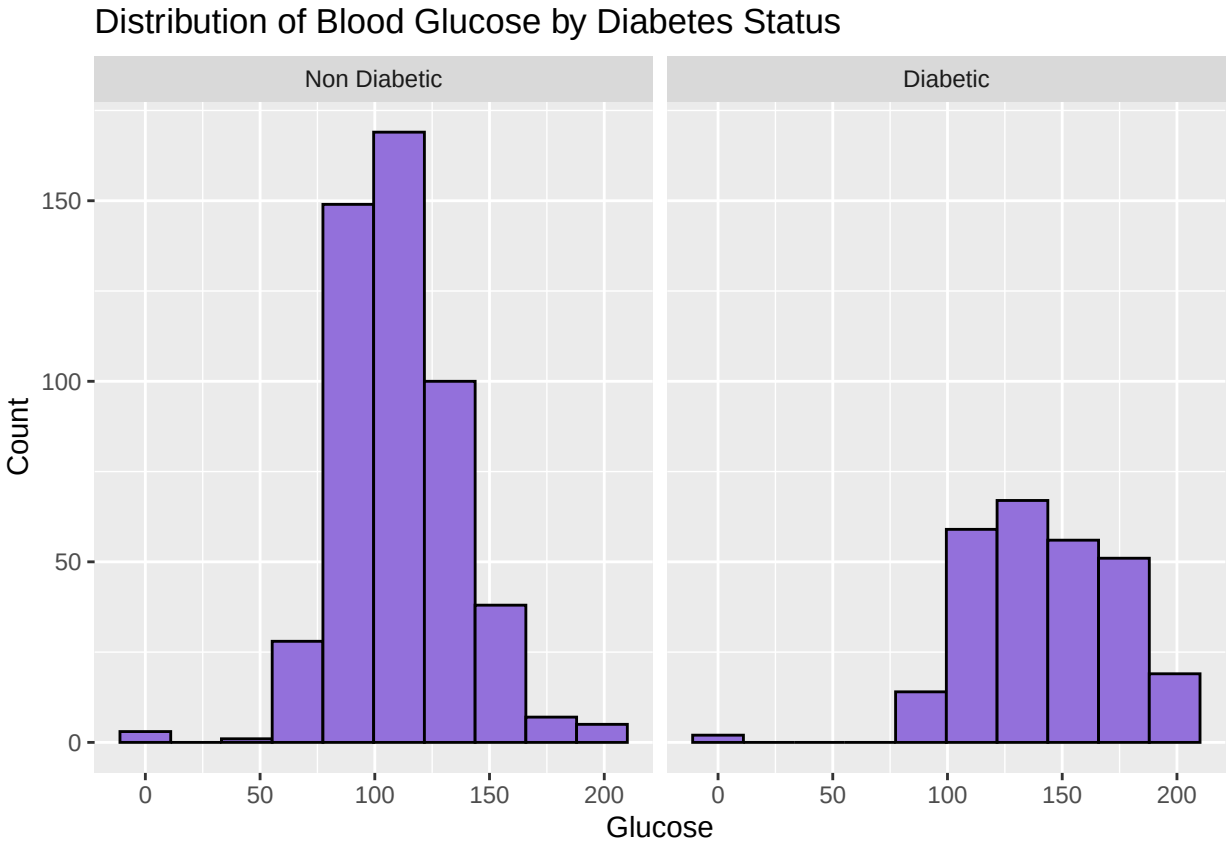
```
diabetes_plot %>%
    ggplot(aes(x = Pregnancies, fill = factor(Outcome))) + geom_histogram(position = "identity",
    bins = 10, colour = "black", fill = "mediumpurple") + facet_wrap(~Outcome) +
    labs(title = "Distribution of Pregnancies by Diabetes Status", x = "Pregnancies",
        y = "Count", fill = "Diabetes Status")
```



We see a non-normal distribution of values, and the number of pregnancies seems to be correlated with diabetes status.

Now, let us plot blood glucose by diabetes status.

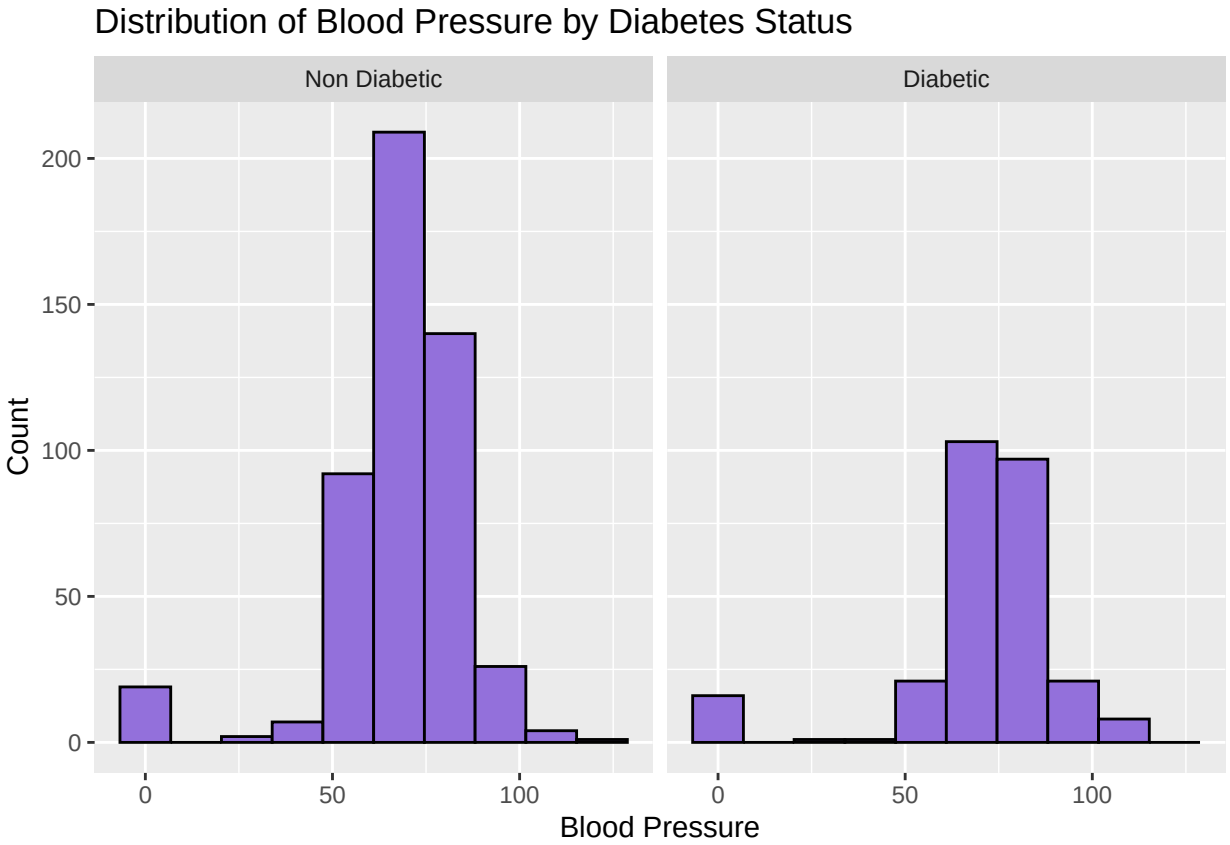
```
diabetes_plot %>%
    ggplot(aes(x = Glucose, fill = factor(Outcome))) + geom_histogram(position = "identity",
    bins = 10, colour = "black", fill = "mediumpurple") + facet_wrap(~Outcome) +
    labs(title = "Distribution of Blood Glucose by Diabetes Status", x = "Glucose",
        y = "Count", fill = "Diabetes Status")
```



The glucose readings of indiviuals with diabetes seem to be skewed to the right. We also see a small sample of 0 readings, which we will need to account for later.

Now, let us plot blood pressure by diabetes status.

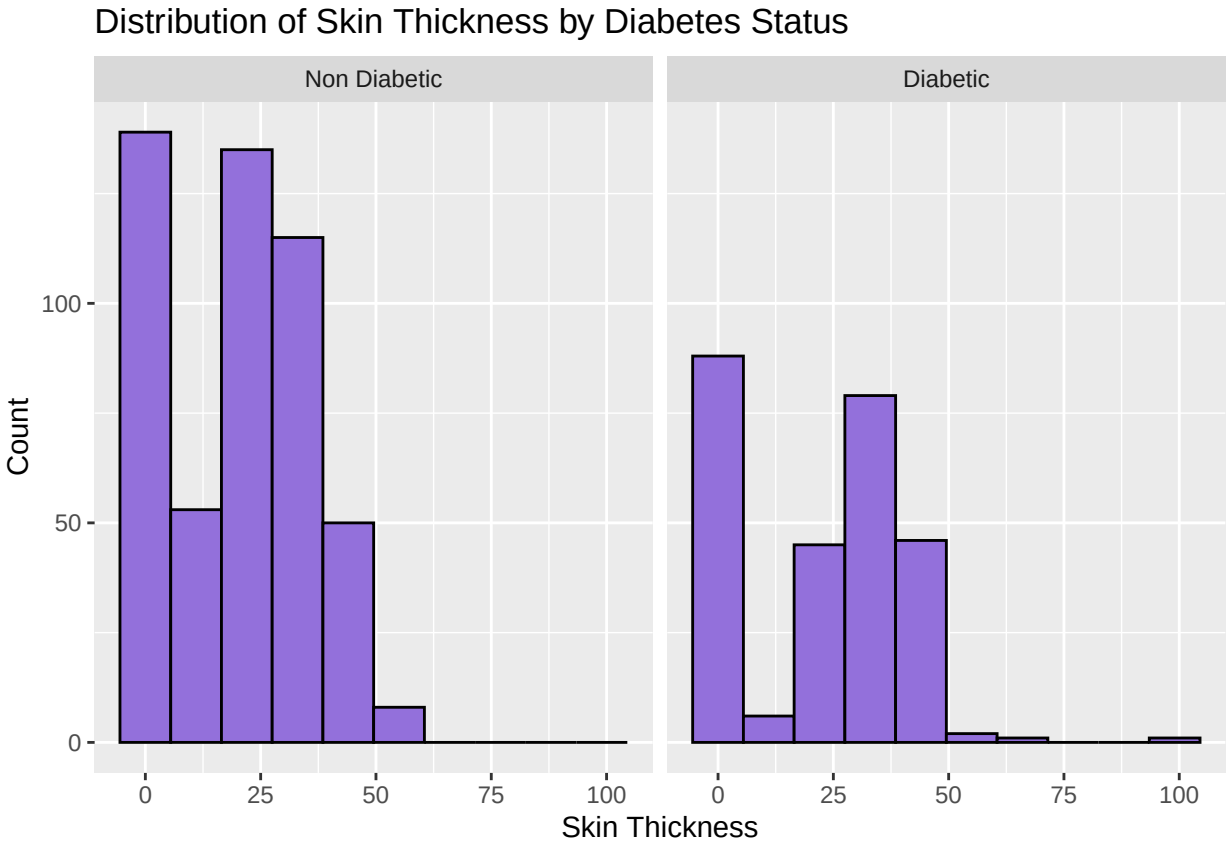
```
diabetes_plot %>%
    ggplot(aes(x = BloodPressure, fill = factor(Outcome))) + geom_histogram(position = "identity",
    bins = 10, colour = "black", fill = "mediumpurple") + facet_wrap(~Outcome) +
    labs(title = "Distribution of Blood Pressure by Diabetes Status", x = "Blood Pressure",
        y = "Count", fill = "Diabetes Status")
```



Again, the readings of individuals with diabetes seem to be skewed slightly to the right. We again see a small sample of 0 readings.

Now, let us plot skin thickness by diabetes status.

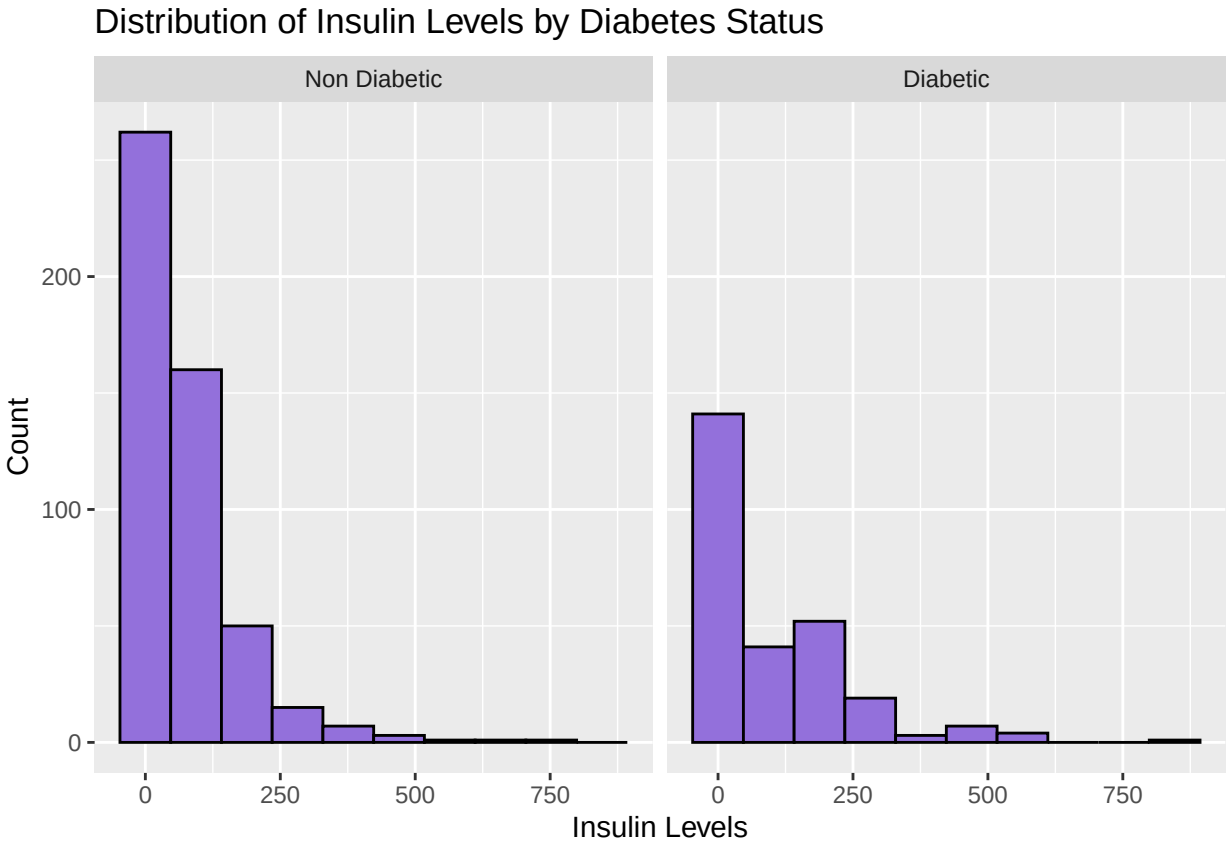
```
diabetes_plot %>%
    ggplot(aes(x = SkinThickness, fill = factor(Outcome))) + geom_histogram(position = "identity",
    bins = 10, colour = "black", fill = "mediumpurple") + facet_wrap(~Outcome) +
    labs(title = "Distribution of Skin Thickness by Diabetes Status", x = "Skin Thickness",
        y = "Count", fill = "Diabetes Status")
```



We see a large sample of 0 readings, which potentially affects the utility of skin thickness as a predictor of diabetes status.

Now, let us plot insulin levels by diabetes status.

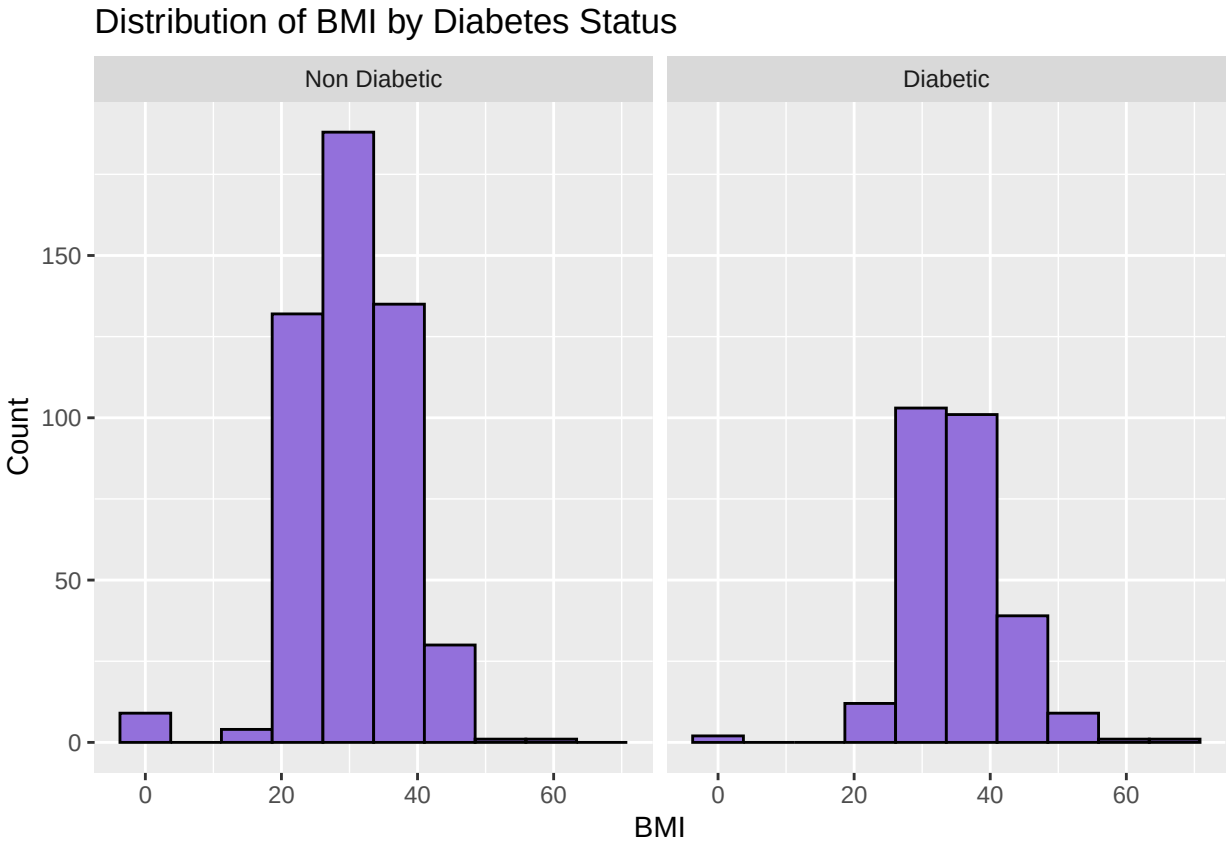
```
diabetes_plot %>%
    ggplot(aes(x = Insulin, fill = factor(Outcome))) + geom_histogram(position = "identity",
    bins = 10, colour = "black", fill = "mediumpurple") + facet_wrap(~Outcome) +
    labs(title = "Distribution of Insulin Levels by Diabetes Status", x = "Insulin Levels",
        y = "Count", fill = "Diabetes Status")
```



Similar to skin thickness, we see a large sample of 0 readings. The readings also appear to be non-normally distributed.

Now, let us plot BMI by diabetes status.

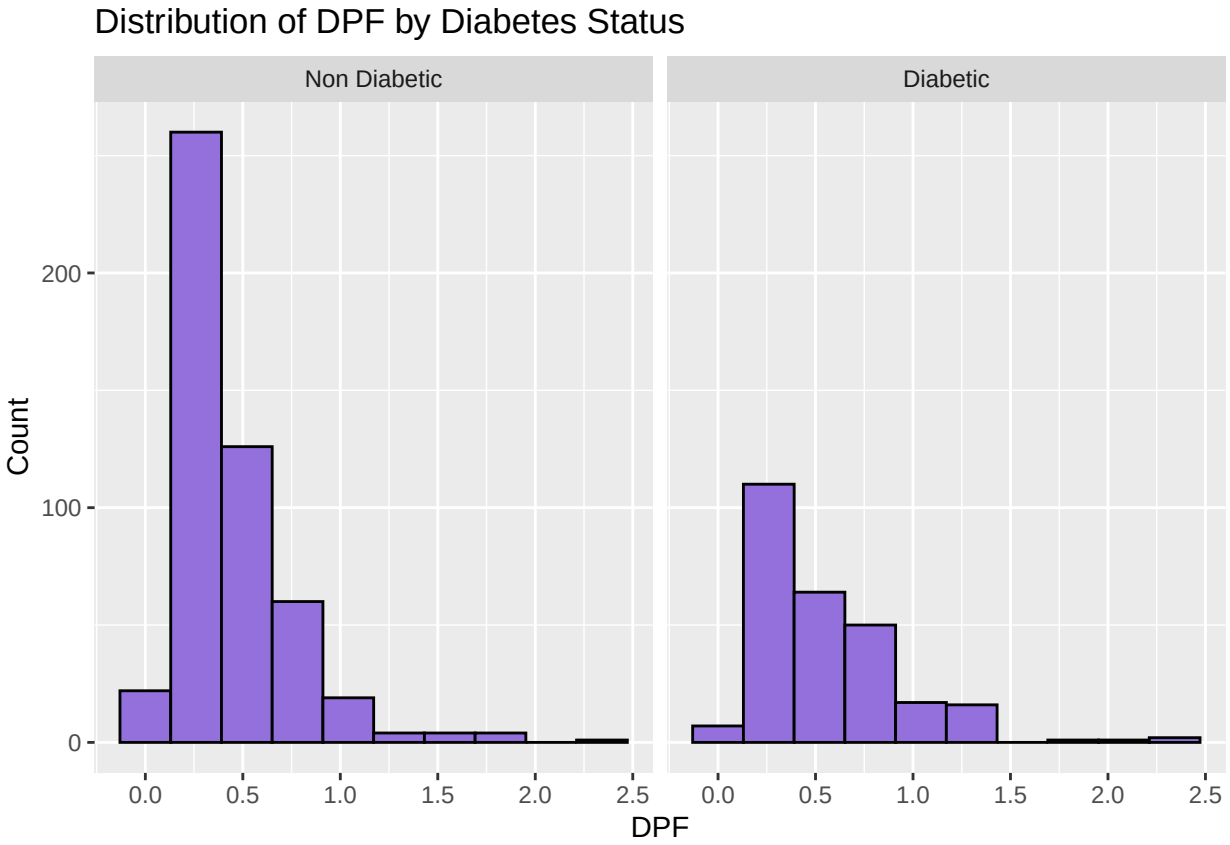
```
diabetes_plot %>%
    ggplot(aes(x = BMI, fill = factor(Outcome))) + geom_histogram(position = "identity",
    bins = 10, colour = "black", fill = "mediumpurple") + facet_wrap(~Outcome) +
    labs(title = "Distribution of BMI by Diabetes Status", x = "BMI", y = "Count",
        fill = "Diabetes Status")
```



The readings of individuals with diabetes seem to be skewed to the right, but both graphs appear fairly normal, with the exception of a small sample of 0 readings.

Now, let us plot DPF by diabetes status.

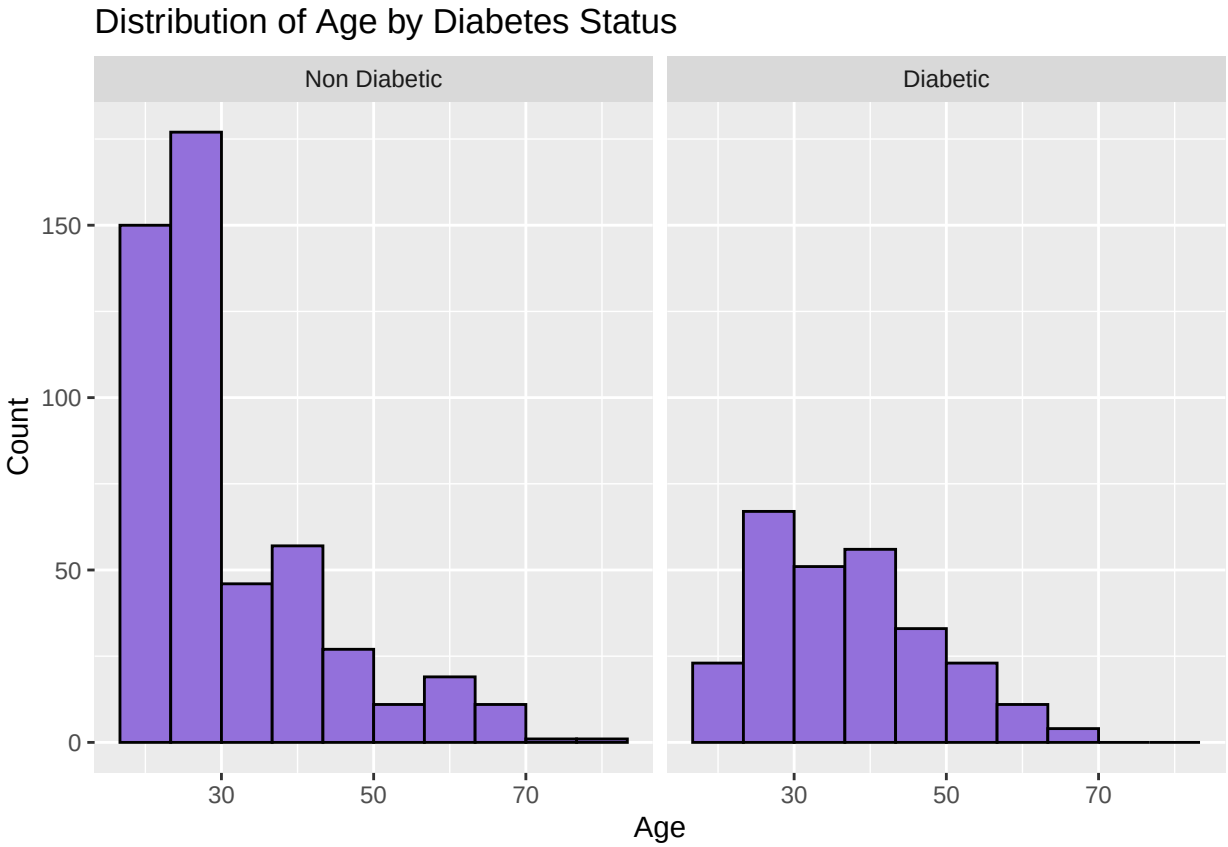
```
diabetes_plot %>%
    ggplot(aes(x = DiabetesPedigreeFunction, fill = factor(Outcome))) + geom_histogram(position = "iden
    bins = 10, colour = "black", fill = "mediumpurple") + facet_wrap(~Outcome) +
    labs(title = "Distribution of DPF by Diabetes Status", x = "DPF", y = "Count",
        fill = "Diabetes Status")
```



The readings of individuals with diabetes seem to be skewed slightly to the right.

Now, let us plot age by diabetes status.

```
diabetes_plot %>%
    ggplot(aes(x = Age, fill = factor(Outcome))) + geom_histogram(position = "identity",
    bins = 10, colour = "black", fill = "mediumpurple") + facet_wrap(~Outcome) +
    labs(title = "Distribution of Age by Diabetes Status", x = "Age", y = "Count",
        fill = "Diabetes Status")
```



It looks like being under 30 puts one at a lower risk of diabetes.

Finally, let us check for correlations between predictors. Remember, we need to first deal with the missing values (coded as 0) for some of the clinical data. Two common ways are to replace the missing values with the mean and the median. Given that some of our variables are not normally distributed, it is more reasonable to use the median. While there are 0 values for pregnancies, we cannot tell which are true 0s, and which are missing values. Therefore, we will leave the pregnancies variable untouched.

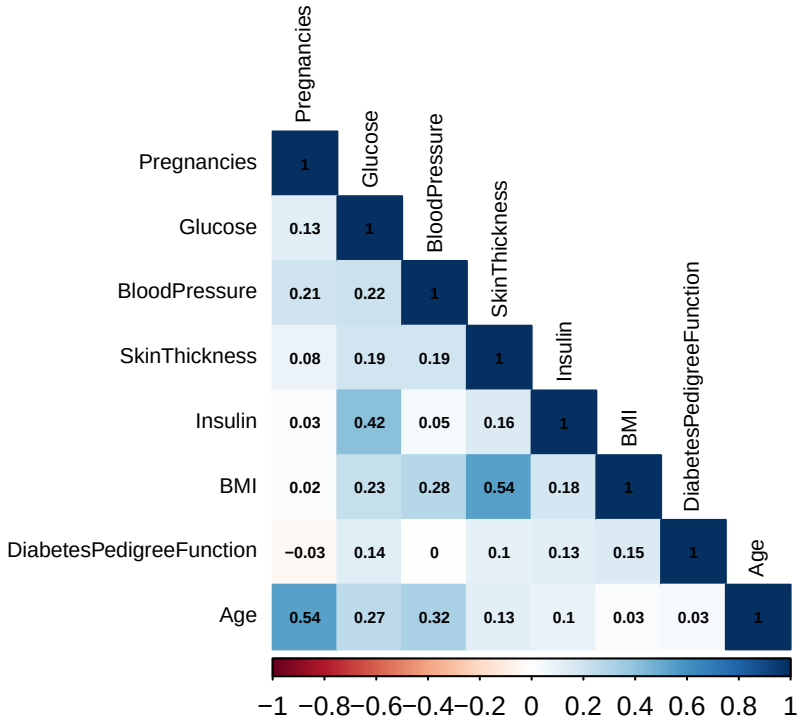
```
diabetes$BloodPressure[diabetes$BloodPressure == 0] <- median(diabetes$BloodPressure[diabetes$BloodPress
    0])
diabetes$Insulin[diabetes$Insulin == 0] <- median(diabetes$Insulin[diabetes$Insulin !=
    0])
diabetes$Glucose[diabetes$Glucose == 0] <- median(diabetes$Glucose[diabetes$Glucose !=
    0])
diabetes$BMI[diabetes$BMI == 0] <- median(diabetes$BMI[diabetes$BMI != 0])
diabetes$SkinThickness[diabetes$SkinThickness == 0] <- median(diabetes$SkinThickness[diabetes$SkinThick
    0])

summary(diabetes)  # To confirm that we have successfully imputed the missing values with median.
```

```
##   Pregnancies        Glucose       BloodPressure    SkinThickness
##  Min.   : 0.000   Min.   : 44.00   Min.   : 24.00   Min.   : 7.00
##  1st Qu.: 1.000   1st Qu.: 99.75   1st Qu.: 64.00   1st Qu.:25.00
##  Median : 3.000   Median :117.00   Median : 72.00   Median :29.00
##  Mean   : 3.845   Mean   :121.66   Mean   : 72.39   Mean   :29.11
##  3rd Qu.: 6.000   3rd Qu.:140.25   3rd Qu.: 80.00   3rd Qu.:32.00
```

```
##  Max.   :17.000   Max.   :199.00   Max.   :122.00   Max.   :99.00
##     Insulin           BMI        DiabetesPedigreeFunction      Age
##  Min.   : 14.0   Min.   :18.20   Min.   :0.0780           Min.   :21.00
##  1st Qu.:121.5   1st Qu.:27.50   1st Qu.:0.2437           1st Qu.:24.00
##  Median :125.0   Median :32.30   Median :0.3725           Median :29.00
##  Mean   :140.7   Mean   :32.46   Mean   :0.4719           Mean   :33.24
##  3rd Qu.:127.2   3rd Qu.:36.60   3rd Qu.:0.6262           3rd Qu.:41.00
##  Max.   :846.0   Max.   :67.10   Max.   :2.4200           Max.   :81.00
##     Outcome
##  Min.   :0.000
##  1st Qu.:0.000
##  Median :0.000
##  Mean   :0.349
##  3rd Qu.:1.000
##  Max.   :1.000
```

We can now check for correlations between predictors.

```
diabetes_correlation <- diabetes[-9]  # Remove Outcome
diabetes_correlation <- cor(diabetes_correlation)
corrplot(diabetes_correlation, method = "color", type = "lower", addCoef.col = "black",
    number.cex = 0.5, tl.cex = 0.7, tl.col = "black")
```



We can observe that BMI and skin thickness are strongly correlated, as are age and number of pregnancies. We also observe that insulin levels and blood glucose levels are moderately correlated, as are age and blood pressure. There are also several weaker correlations.

Constructing and Evaluating Models

It is time to construct our models. We will split our data into a validation and a final test set, and further split the validation set into a training and test set. We will then train our models using the caret package, and evaluate their accuracy and AUC scores. Finally, we will construct and evaluate ensemble models through a voting approach. We will then evaluate our chosen model's performance on the final test set.

Let's create our training and test sets. But first, let's code the outcome as a factor before splitting the data to allow us to build our model.

```
diabetes$Outcome <- factor(diabetes$Outcome)
```

We create a final test set using 20% of the diabetes dataset. Then, we will create training (80%) and test (20%) sets from the remaining data.

```
set.seed(123, sample.kind = "Rounding")  # if using R 3.6 or later
test_index <- createDataPartition(y = diabetes$Outcome, times = 1, p = 0.2, list = FALSE)
validation_index <- diabetes[-test_index, ]
final_test_set <- diabetes[test_index, ]

validation_index <- createDataPartition(y = diabetes$Outcome, p = 0.2, list = FALSE)
train_set <- diabetes[-validation_index, ]
test_set <- diabetes[validation_index, ]

rm(test_index, validation_index)  # Removing the unneeded dataset
```

For all models, we will apply cross validation and tune parameters for optimisation where applicable. Let us construct and evaluate our first model: GLM.

```
train_glm <- train(Outcome ~ .,
                   method = "glm",
                   trControl = trainControl(method = "cv", number = 10, p = .9), # To apply cross valid
                   data = train_set)

summary(train_glm) # This is for visualising the importance of each predictor in the model
```

```
##
## Call:
## NULL
##
## Coefficients:
##                            Estimate Std. Error z value Pr(>|z|)
## (Intercept)              -8.946858   0.890268 -10.050  < 2e-16 ***
## Pregnancies               0.104972   0.034632   3.031  0.00244 **
## Glucose                   0.036503   0.004372   8.350  < 2e-16 ***
## BloodPressure            -0.010950   0.009372  -1.168  0.24264
## SkinThickness             0.006898   0.014587   0.473  0.63628
## Insulin                  -0.002013   0.001332  -1.512  0.13053
## BMI                       0.095384   0.019545   4.880 1.06e-06 ***
## DiabetesPedigreeFunction  0.924466   0.332968   2.776  0.00550 **
## Age                       0.018464   0.010481   1.762  0.07813 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 793.94  on 613  degrees of freedom
## Residual deviance: 580.39  on 605  degrees of freedom
## AIC: 598.39
##
## Number of Fisher Scoring iterations: 5
```

```
predict_glm <- predict(train_glm, newdata = test_set, type = "raw")

results <- tibble(method = "GLM",
                          accuracy = confusionMatrix(predict_glm, test_set$Outcome)$overall[["Accuracy
                          AUC = as.numeric(roc(test_set$Outcome, as.numeric(predict_glm))$auc) # To ev
                  )
```

```
## Setting levels: control = 0, case = 1
```

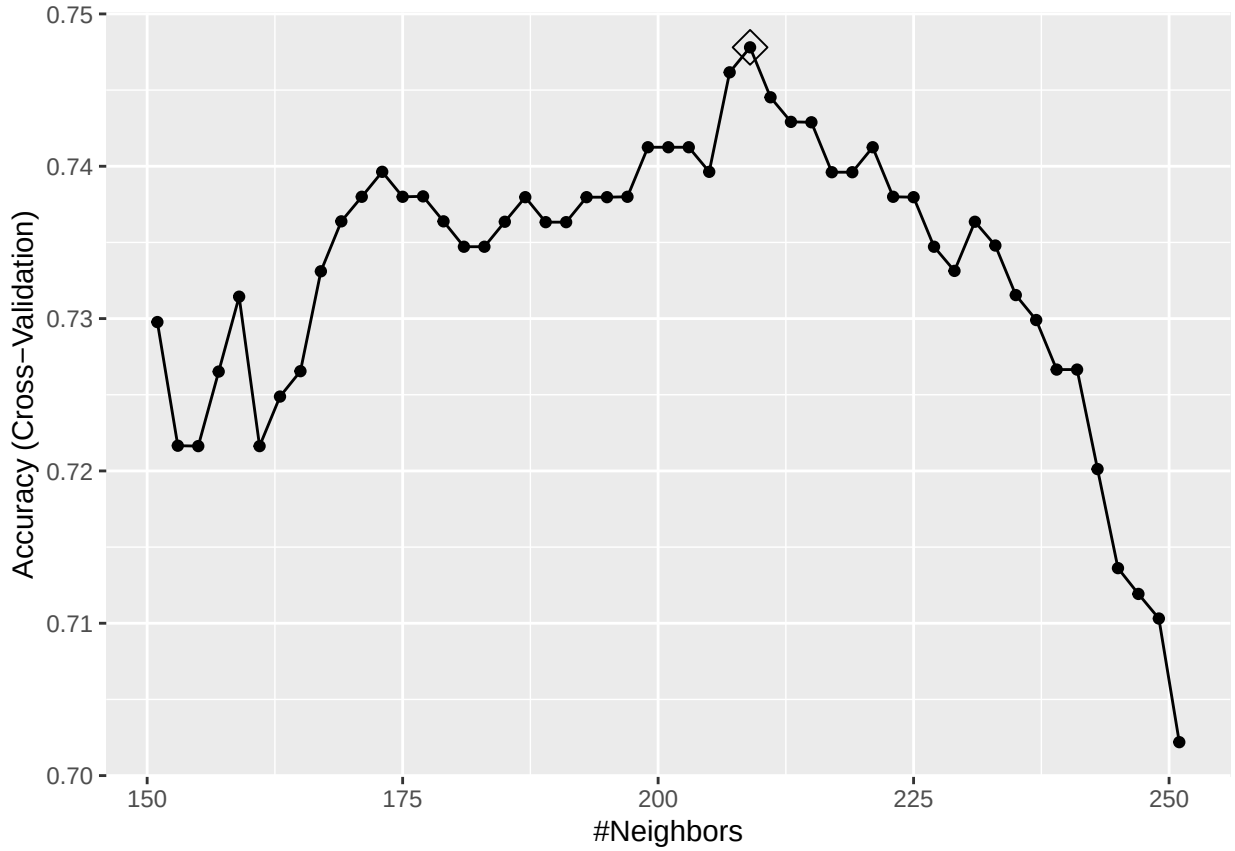
```
## Setting direction: controls < cases
```

```
results
```

```
## # A tibble: 1 x 3
##   method accuracy   AUC
##   <chr>     <dbl> <dbl>
## 1 GLM       0.818 0.783
```

We see that our GLM model has an accuracy of 0.818, and AUC of 0.783. Not too bad! Can we do better? Let us move on to our next model: KNN.

```
set.seed(123)
train_knn <- train(Outcome ~ ., method = "knn", data = train_set, tuneGrid = data.frame(k = seq(151,
    251, 2)), trControl = trainControl(method = "cv", number = 10, p = 0.9))

ggplot(train_knn, highlight = TRUE)  # to visualise the relationship between k and accuracy
```




```
varImp(train_knn)
```

```
## ROC curve variable importance
##
##                           Importance
## Glucose                      100.000
## BMI                           52.784
## Age                           47.516
## Insulin                       29.094
## SkinThickness                 20.787
## Pregnancies                    7.368
## BloodPressure                  1.221
## DiabetesPedigreeFunction       0.000
```

```
train_knn$bestTune  # to find the best k parameter
```

```
##      k
## 30 209
```

```
train_knn$finalModel
```

```
## 209-nearest neighbor model
## Training set outcome distribution:
##
```

```
##   0   1
## 400 214
```

```
predict_knn <- predict(train_knn, newdata = test_set, type = "raw")

results <- bind_rows(results, tibble(method = "KNN", accuracy = confusionMatrix(predict_knn,
    test_set$Outcome)$overall[["Accuracy"]], AUC = as.numeric(roc(test_set$Outcome,
    as.numeric(predict_knn))$auc)))
```

```
## Setting levels: control = 0, case = 1
```

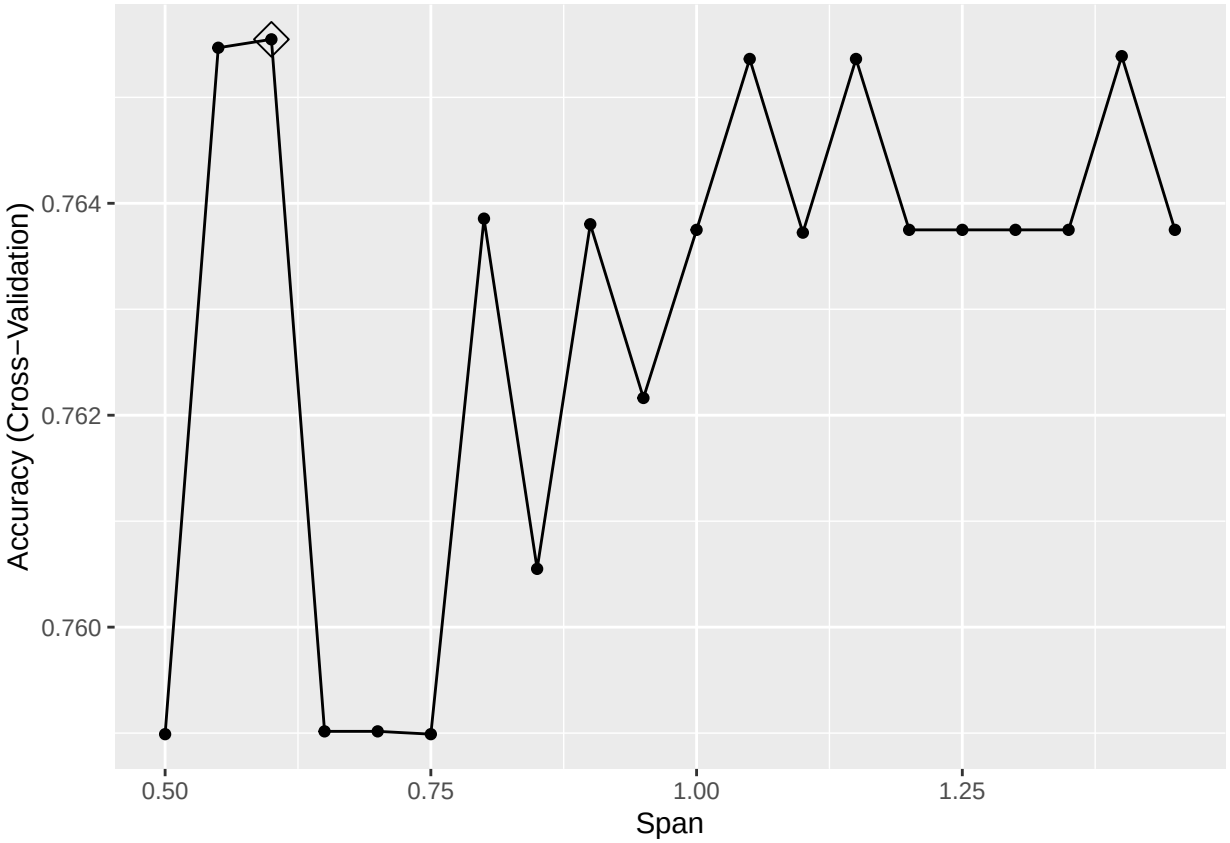
```
## Setting direction: controls < cases
```

```
results
```

```
## # A tibble: 2 x 3
##   method accuracy   AUC
##   <chr>     <dbl> <dbl>
## 1 GLM       0.818 0.783
## 2 KNN       0.812 0.770
```

Our KNN model has an accuracy of 0.812, and AUC of 0.770, performing slightly worse than our GLM model. For our next model: LOESS

```
train_loess <- train(Outcome ~ ., method = "gamLoess", tuneGrid = expand.grid(span = seq(0.5,
    1.45, len = 20), degree = 1), trControl = trainControl(method = "cv", number = 10,
    p = 0.9), data = train_set)

ggplot(train_loess, highlight = TRUE)
```




```
predict_loess <- predict(train_loess, newdata = test_set, type = "raw")

results <- bind_rows(results, tibble(method = "LOESS", accuracy = confusionMatrix(predict_loess,
    test_set$Outcome)$overall[["Accuracy"]], AUC = as.numeric(roc(test_set$Outcome,
    as.numeric(predict_loess))$auc)))
```

```
## Setting levels: control = 0, case = 1
```

```
## Setting direction: controls < cases
```

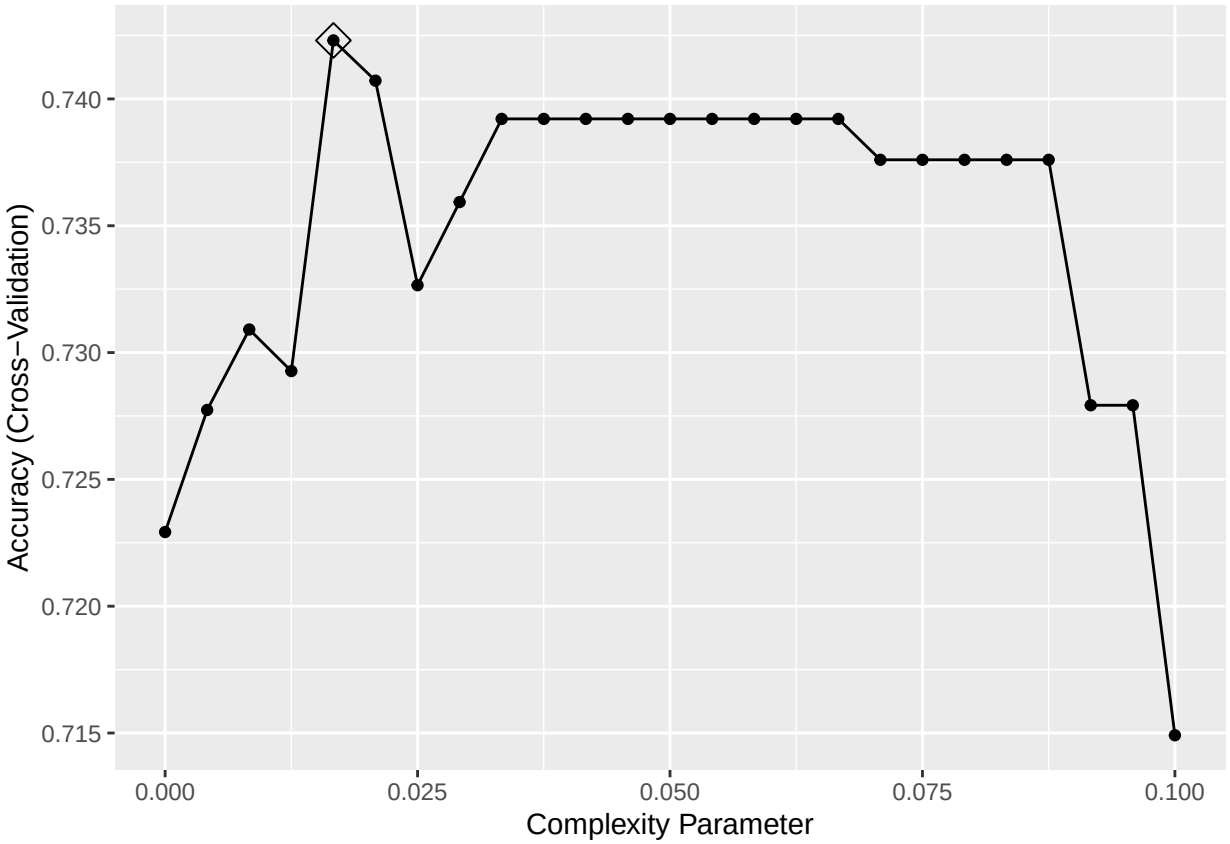
```
results
```

```
## # A tibble: 3 x 3
##   method accuracy   AUC
##   <chr>     <dbl> <dbl>
## 1 GLM       0.818 0.783
## 2 KNN       0.812 0.770
## 3 LOESS     0.786 0.763
```

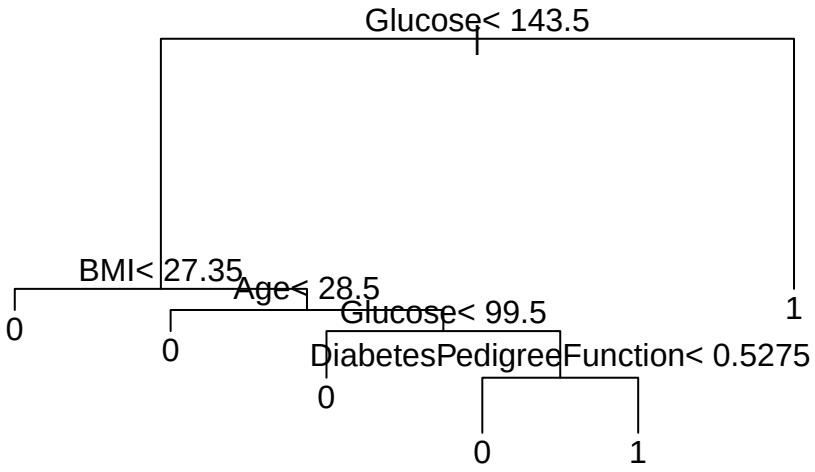
Our LOESS model has an accuracy of 0.786, and AUC of 0.763. On to our next model: rpart

```
train_rpart <- train(Outcome ~ ., method = "rpart", tuneGrid = data.frame(cp = seq(0,
    0.1, len = 25)), trControl = trainControl(method = "cv", number = 10, p = 0.9),
    data = train_set)
```

```r
# display the decision tree
ggplot(train_rpart, highlight = TRUE)
```




```r
# view the final decision tree
plot(train_rpart$finalModel, margin = 0.1)  # to plot tree structure
text(train_rpart$finalModel)  # add text labels
```




```
predict_rpart <- predict(train_rpart, newdata = test_set, type = "raw")

results <- bind_rows(results, tibble(method = "Decision Tree", accuracy = confusionMatrix(predict_rpart
    test_set$Outcome)$overall[["Accuracy"]], AUC = as.numeric(roc(test_set$Outcome,
    as.numeric(predict_rpart))$auc)))
```

```
## Setting levels: control = 0, case = 1
```

```
## Setting direction: controls < cases
```

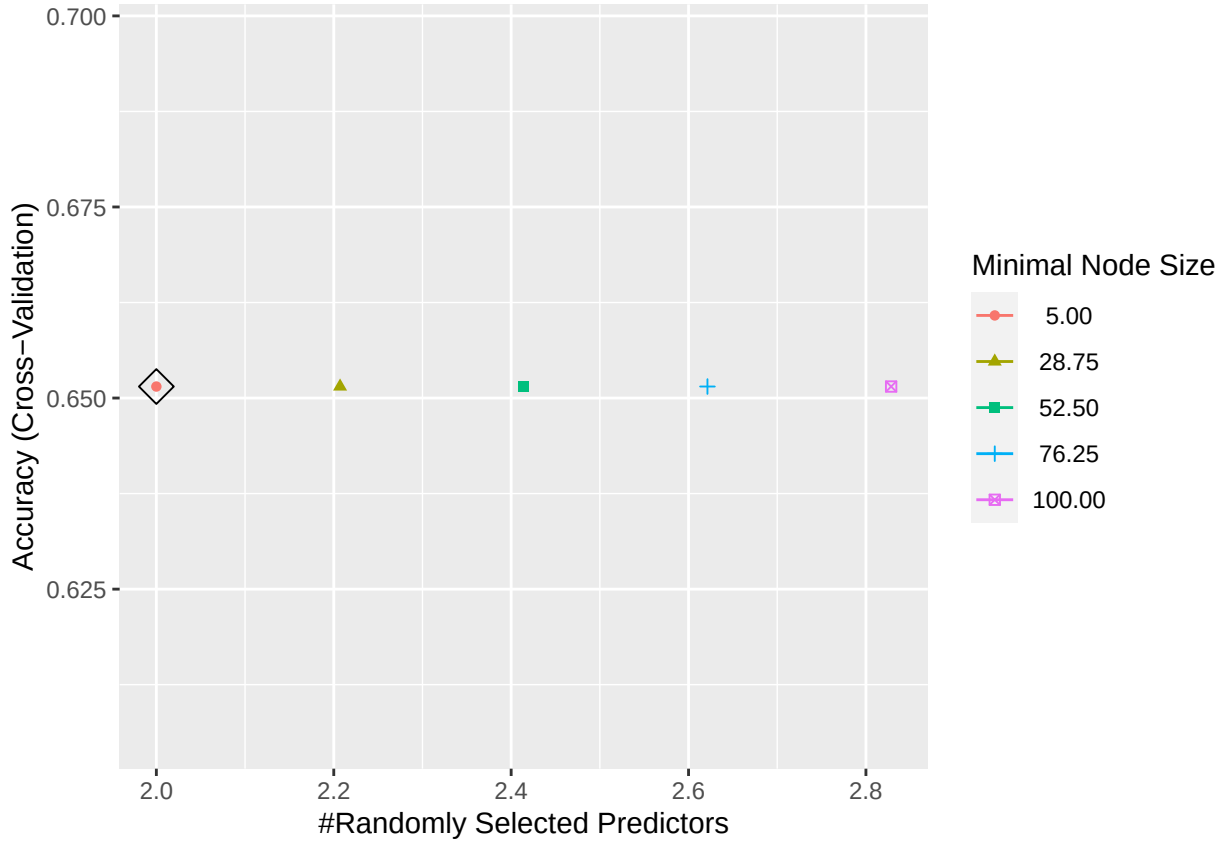
```
results
```

```
## # A tibble: 4 x 3
##   method        accuracy   AUC
##   <chr>            <dbl> <dbl>
## 1 GLM              0.818 0.783
## 2 KNN              0.812 0.770
## 3 LOESS            0.786 0.763
## 4 Decision Tree    0.779 0.745
```

Our rpart model has an accuracy of 0.779, and AUC of 0.745. Let's look at the next model: RF

```
train_rf <- train(Outcome ~ ., method = "Rborist", tuneGrid = data.frame(predFixed = seq(2,
    sqrt(ncol(train_set) - 1), length = 5), minNode = seq(5, 100, length = 5)), trControl = trainControl
    number = 10, p = , 9), data = train_set)

ggplot(train_rf, highlight = TRUE)
```

```
## `geom_line()`: Each group consists of only one observation.
## i Do you need to adjust the group aesthetic?
```




```
predict_rf <- predict(train_rf, newdata = test_set, type = "raw")

results <- bind_rows(results, tibble(method = "Random Forest", accuracy = confusionMatrix(predict_rf,
    test_set$Outcome)$overall[["Accuracy"]], AUC = as.numeric(roc(test_set$Outcome,
    as.numeric(predict_rf))$auc)))
```

```
## Setting levels: control = 0, case = 1
## Setting direction: controls < cases
```

```
results
```

```
## # A tibble: 5 x 3
##   method        accuracy   AUC
##   <chr>            <dbl> <dbl>
```

```
## 1 GLM              0.818 0.783
## 2 KNN              0.812 0.770
## 3 LOESS            0.786 0.763
## 4 Decision Tree    0.779 0.745
## 5 Random Forest    0.649 0.5
```

Our rf model has an accuracy of 0.649, and AUC of 0.5, making it the worst performer so far, particularly in AUC. For our next model: XGB

```
train_xgb <- train(Outcome ~ .,
                  method = "xgbTree",
                  tuneGrid = expand.grid( # Creating a tuning parameter
                    nrounds = seq(25, 250, length = 10),
                    max_depth = c(2, 4, 6, 8),
                    eta = c(0.05, 0.1, 0.2),
                    gamma = 0,
                    colsample_bytree = 1,
                    min_child_weight = 1,
                    subsample = 1),
                  trControl = trainControl(method = "cv", number = 10, p = .9),
                  objective = "binary:logistic",
                  data = train_set) # for binary classification
```

```
## [17:24:18] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [17:24:18] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
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## [17:24:20] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
## [17:24:21] WARNING: src/c_api/c_api.cc:935: `ntree_limit` is deprecated, use `iteration_range` instea
```

```
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## [17:24:25] WARNING: src/c_api/c_api.cc:935: ‘ntree_limit‘ is deprecated, use ‘iteration_range‘ instea
## [17:24:26] WARNING: src/c_api/c_api.cc:935: ‘ntree_limit‘ is deprecated, use ‘iteration_range‘ instea
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## [17:24:26] WARNING: src/c_api/c_api.cc:935: ‘ntree_limit‘ is deprecated, use ‘iteration_range‘ instea
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```
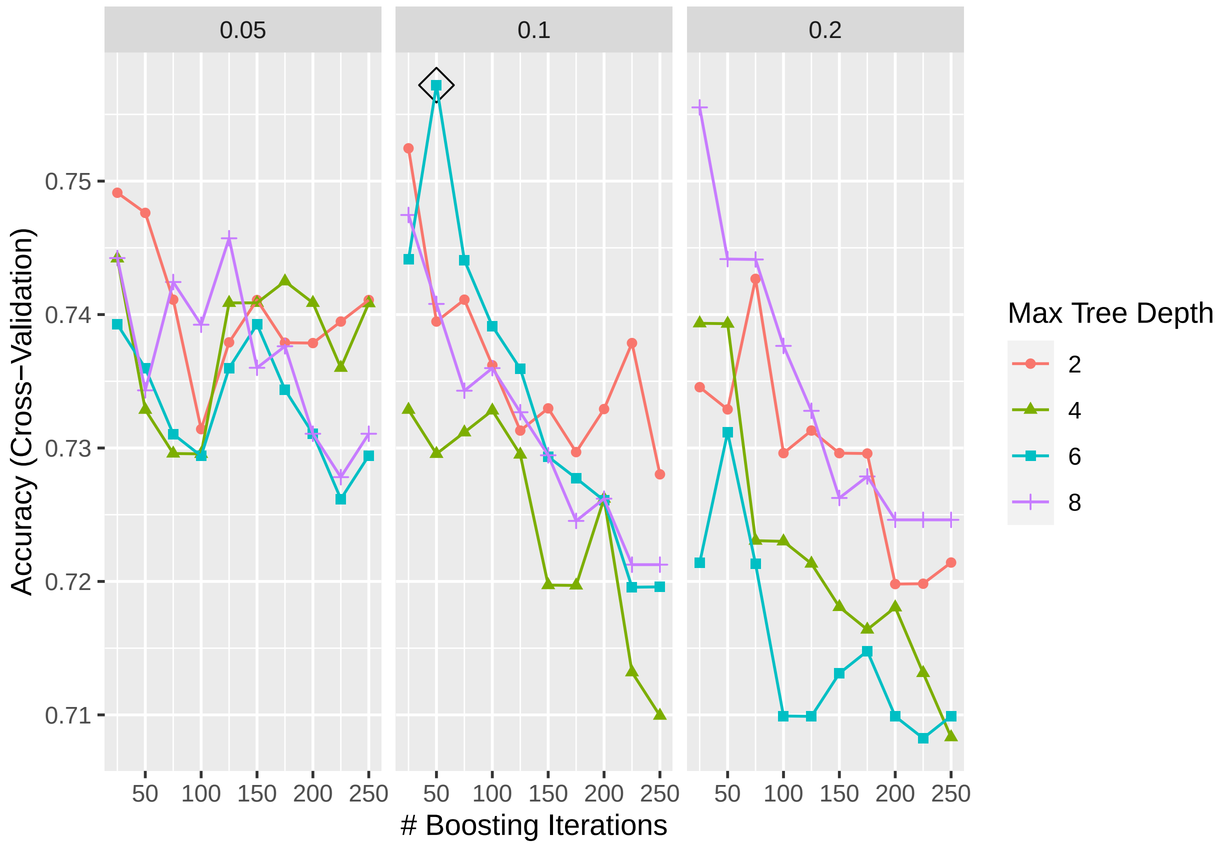

```r
ggplot(train_xgb, highlight = TRUE)
```



```
predict_xgb <- predict(train_xgb, newdata = test_set, type = "raw")

results <- bind_rows(results,
                     tibble(method = "Extreme Gradient Boosting",
                            accuracy = confusionMatrix(predict_xgb, test_set$Outcome)$overall[["Accuracy
                            AUC = as.numeric(roc(test_set$Outcome, as.numeric(predict_xgb))$auc))
                     )
```

```
## Setting levels: control = 0, case = 1
```

```
## Setting direction: controls < cases
```

```
results
```

```
## # A tibble: 6 x 3
##   method                     accuracy   AUC
##   <chr>                         <dbl> <dbl>
## 1 GLM                           0.818 0.783
## 2 KNN                           0.812 0.770
## 3 LOESS                         0.786 0.763
## 4 Decision Tree                 0.779 0.745
## 5 Random Forest                 0.649 0.5
## 6 Extreme Gradient Boosting     0.792 0.768
```

Our XGB model has an accuracy of 0.792, and AUC of 0.768. For our final standalone model: NB.

```
train_nb <- train(Outcome ~ ., method = "nb", trControl = trainControl(method = "cv",
    number = 10, p = 0.9), data = train_set)

predict_nb <- predict(train_nb, newdata = test_set, type = "raw")

results <- bind_rows(results, tibble(method = "Naive Bayes", accuracy = confusionMatrix(predict_nb,
    test_set$Outcome)$overall[["Accuracy"]], AUC = as.numeric(roc(test_set$Outcome,
    as.numeric(predict_nb))$auc)))
```

```
## Setting levels: control = 0, case = 1
```

```
## Setting direction: controls < cases
```

```
results
```

```
## # A tibble: 7 x 3
##   method                     accuracy   AUC
##   <chr>                         <dbl> <dbl>
## 1 GLM                           0.818 0.783
## 2 KNN                           0.812 0.770
## 3 LOESS                         0.786 0.763
## 4 Decision Tree                 0.779 0.745
## 5 Random Forest                 0.649 0.5
## 6 Extreme Gradient Boosting     0.792 0.768
## 7 Naive Bayes                   0.766 0.739
```

Our NB model has an accuracy of 0.766, and AUC of 0.739.

As it stands, our GLM model has the best performance, followed by KNN, XGB, and LOESS, in that order. Let us create 3 ensemble models by majority voting, using the top 4, best 3, and best 2 models.

Let us start by creating a Top 4 ensemble model.

```
# We first combine the predictions of the top 4 models into a data frame.
top4_votes <- data.frame(predict_glm, predict_knn, predict_loess, predict_xgb)
top4_votes <- sapply(top4_votes, as.numeric)  # Converting to numeric values for analysis in next secti

# Apply majority voting to get final ensemble prediction
predict_top4_ensemble <- ifelse(rowMeans(top4_votes) > 1, "1", "0")  # Converting factor into numeric v

results <- bind_rows(results, tibble(method = "GLM + KNN + XGB + LOESS Ensemble",
    accuracy = mean(predict_top4_ensemble == test_set$Outcome), AUC = as.numeric(roc(test_set$Outcome,
        as.numeric(predict_top4_ensemble))$auc)))
```

```
## Setting levels: control = 0, case = 1
```

```
## Setting direction: controls < cases
```

```
results
```

```
## # A tibble: 8 x 3
##   method                           accuracy   AUC
##   <chr>                               <dbl> <dbl>
## 1 GLM                                 0.818 0.783
## 2 KNN                                 0.812 0.770
## 3 LOESS                               0.786 0.763
## 4 Decision Tree                       0.779 0.745
## 5 Random Forest                       0.649 0.5
## 6 Extreme Gradient Boosting           0.792 0.768
## 7 Naive Bayes                         0.766 0.739
## 8 GLM + KNN + XGB + LOESS Ensemble    0.779 0.783
```

Our Top 4 ensemble model has an accuracy of 0.779, and AUC of 0.783. Let's apply the same method to create a Top 3 ensemble model.

```
# Combine predictions into a data frame
top3_votes <- data.frame(predict_glm, predict_knn, predict_xgb)
top3_votes <- sapply(top3_votes, as.numeric)  # Converting to numeric values for analysis in next secti

# Apply majority voting to get final ensemble prediction
predict_top3_ensemble <- ifelse(rowMeans(top3_votes) > 1, "1", "0")

results <- bind_rows(results, tibble(method = "GLM + KNN + XGB Ensemble", accuracy = mean(predict_top3_
    test_set$Outcome), AUC = as.numeric(roc(test_set$Outcome, as.numeric(predict_top3_ensemble))$auc)))
```

```
## Setting levels: control = 0, case = 1
```

```
## Setting direction: controls < cases
```

```
results
```

```
## # A tibble: 9 x 3
##   method                             accuracy   AUC
##   <chr>                                 <dbl> <dbl>
## 1 GLM                                   0.818 0.783
## 2 KNN                                   0.812 0.770
## 3 LOESS                                 0.786 0.763
## 4 Decision Tree                         0.779 0.745
## 5 Random Forest                         0.649 0.5
## 6 Extreme Gradient Boosting             0.792 0.768
## 7 Naive Bayes                           0.766 0.739
## 8 GLM + KNN + XGB + LOESS Ensemble      0.779 0.783
## 9 GLM + KNN + XGB Ensemble              0.792 0.785
```

Our Top 3 ensemble model has an accuracy of 0.792, and AUC of 0.785. Let us create our Top 2 ensemble model.

```
# Combine predictions into a data frame
top2_votes <- data.frame(predict_glm, predict_knn)
top2_votes <- sapply(top2_votes, as.numeric)  # Converting to numeric values for analysis in next secti

# Apply majority voting to get final ensemble prediction
predict_top2_ensemble <- ifelse(rowMeans(top2_votes) > 1, "1", "0")  # Converting to numeric in the pre

results <- bind_rows(results, tibble(method = "Top 2 Ensemble", accuracy = mean(predict_top2_ensemble ==
    test_set$Outcome), AUC = as.numeric(roc(test_set$Outcome, as.numeric(predict_top2_ensemble))$auc)))
```

```
## Setting levels: control = 0, case = 1
```

```
## Setting direction: controls < cases
```

```
results
```

```
## # A tibble: 10 x 3
##    method                            accuracy   AUC
##    <chr>                                <dbl> <dbl>
##  1 GLM                                  0.818 0.783
##  2 KNN                                  0.812 0.770
##  3 LOESS                                0.786 0.763
##  4 Decision Tree                        0.779 0.745
##  5 Random Forest                        0.649 0.5
##  6 Extreme Gradient Boosting            0.792 0.768
##  7 Naive Bayes                          0.766 0.739
##  8 GLM + KNN + XGB + LOESS Ensemble     0.779 0.783
##  9 GLM + KNN + XGB Ensemble             0.792 0.785
## 10 Top 2 Ensemble                       0.818 0.792
```

Our Top 2 ensemble model has an accuracy of 0.818, and AUC of 0.792.

Final Evaluation

We have constructed and evaluated several standalone and ensemble models. The three best performing models, GLM, KNN, and GLM + KNN ensemble are pretty evenly matched, with KNN being slightly inferior. Let us now evaluate all 3 models on our final test set.

```
predict_glm_final <- predict(train_glm, newdata = final_test_set, type = "raw")
predict_knn_final <- predict(train_knn, newdata = final_test_set, type = "raw")

final_votes <- data.frame(predict_glm_final, predict_knn_final)
final_votes <- sapply(final_votes, as.numeric)

predict_final_ensemble <- ifelse(rowMeans(final_votes) > 1, "1", "0")

final_results <- tibble(method = c("GLM", "KNN", "Top 2 Ensemble"), accuracy = c(confusionMatrix(predict
    final_test_set$Outcome)$overall[["Accuracy"]], confusionMatrix(predict_knn_final,
    final_test_set$Outcome)$overall[["Accuracy"]], mean(predict_final_ensemble ==
    final_test_set$Outcome)), AUC = c(as.numeric(roc(final_test_set$Outcome, as.numeric(predict_glm_fina
    as.numeric(roc(final_test_set$Outcome, as.numeric(predict_knn_final))$auc), as.numeric(roc(final_tes
        as.numeric(predict_final_ensemble))$auc)))
```

```
## Setting levels: control = 0, case = 1

## Setting direction: controls < cases

## Setting levels: control = 0, case = 1

## Setting direction: controls < cases

## Setting levels: control = 0, case = 1

## Setting direction: controls < cases
```

```
final_results
```

```
## # A tibble: 3 x 3
##   method         accuracy   AUC
##   <chr>             <dbl> <dbl>
## 1 GLM               0.805 0.773
## 2 KNN               0.773 0.727
## 3 Top 2 Ensemble    0.786 0.767
```

We see that the GLM model is the most robust, with an accuracy of 0.805, and AUC of 0.773.

Conclusion

In this project, we attempted to create a diabetes risk prediction model that effectively predicts diabetes status in a population of females of Pima Indian heritage, aged 21 years and above, using 8 medical predictors.

We evaluated several standalone models and ensemble models on accuracy and AUC scores, and found the humble GLM model to be most effective in predicting diabetes status with accuracy and AUC scores of 0.805, and 0.773 respectively. For this project, we worked with a small dataset, with relatively few number of predictors. Nonetheless, the same basic principles can apply with more complex datasets. Further optimisations can also be obtained with other techniques, such as feature engineering and oversampling.

I hope you found this little exercise useful.

References

1. World Health Organisation (n.d.). *Diabetes.* https://www.who.int/health-topics/diabetes#tab=tab_1
2. International Diabetes Atlas (n.d.). *Diabetes around the world in 2021.* https://diabetesatlas.org/