

Assignment2-Mukhtar

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R Markdown

This is an R Markdown document. Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see <http://rmarkdown.rstudio.com>.

When you click the **Knit** button a document will be generated that includes both content as well as the output of any embedded R code chunks within the document. You can embed an R code chunk like this:

```
getwd()
```

```
## [1] "C:/Users/Mukht/OneDrive/Desktop/Kent State University/College of Business Admin-Bus. Analytics I"
```

```
setwd("C:\\Users\\Mukht\\OneDrive\\Desktop\\Kent State University\\College of Business Admin-Bus. Analy
```

```
Assignment2_UpdateNew <-read.csv("UniversalBank.csv")
```

```
is.na(Assignment2_UpdateNew[,1:14])
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```

```
library(caret)
```

```
## Loading required package: ggplot2
```

```
## Loading required package: lattice
```

```
library(lattice)
library(ggplot2)
library(ISLR)
summary(Assignment2_UpdateNew)
```

```
##      Age      Experience      Income      Family
## Min.   :23.00   Min.   : -3.0   Min.    :  8.00   Min.    :1.000
## 1st Qu.:35.00   1st Qu.:10.0   1st Qu.: 39.00   1st Qu.:1.000
## Median :45.00   Median :20.0   Median : 64.00   Median :2.000
## Mean   :45.34   Mean   :20.1   Mean    : 73.77   Mean    :2.396
## 3rd Qu.:55.00   3rd Qu.:30.0   3rd Qu.: 98.00   3rd Qu.:3.000
## Max.   :67.00   Max.   :43.0   Max.    :224.00   Max.    :4.000
##      CCAvg      Education_1 Education_2 Education_3 Mortgage
## Min.    : 0.000   Min.    :0   Min.    :0.0000   Min.    :0   Min.    : 0.0
## 1st Qu.: 0.700   1st Qu.:0   1st Qu.:0.0000   1st Qu.:0   1st Qu.: 0.0
## Median : 1.500   Median :0   Median :0.0000   Median :0   Median : 0.0
## Mean    : 1.938   Mean    :0   Mean    :0.4192   Mean    :0   Mean    : 56.5
## 3rd Qu.: 2.500   3rd Qu.:0   3rd Qu.:1.0000   3rd Qu.:0   3rd Qu.:101.0
## Max.    :10.000   Max.    :0   Max.    :1.0000   Max.    :0   Max.    :635.0
## Personal.Loan Securities.Account CD.Account      Online
## Min.    :0.000   Min.    :0.0000   Min.    :0.0000   Min.    :0.0000
## 1st Qu.:0.000   1st Qu.:0.0000   1st Qu.:0.0000   1st Qu.:0.0000
## Median :0.000   Median :0.0000   Median :0.0000   Median :1.0000
## Mean    :0.096   Mean    :0.1044   Mean    :0.0604   Mean    :0.5968
## 3rd Qu.:0.000   3rd Qu.:0.0000   3rd Qu.:0.0000   3rd Qu.:1.0000
## Max.    :1.000   Max.    :1.0000   Max.    :1.0000   Max.    :1.0000
##      CreditCard
## Min.    :0.000
## 1st Qu.:0.000
## Median :0.000
## Mean    :0.294
## 3rd Qu.:1.000
## Max.    :1.000
```

```
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##      filter, lag

## The following objects are masked from 'package:base':
##
##      intersect, setdiff, setequal, union
```

```
m_Assignment2_UpdateNew <-select(Assignment2_UpdateNew,Personal.Loan,Education_1,Education_2,Education_3)
```

```
# Data Partitioning into Training-60% and Validation-4
set.seed(15)
```



```

Test_Index = createDataPartition(m_Assignment2_UpdateNew$Personal.Loan,p=0.4, list=FALSE) # 40% reserve
Test_Data = m_Assignment2_UpdateNew[Test_Index,]
TraVal_Data = m_Assignment2_UpdateNew[-Test_Index,] # Validation and Training data is rest

Train_Index = createDataPartition(TraVal_Data$Personal.Loan,p=0.60, list=FALSE) # 60% of remaining data
Train_Data = TraVal_Data[Train_Index,]
Validation_Data = TraVal_Data[-Train_Index,] # rest as validation

summary(TraVal_Data)

```

```

## Personal.Loan      Education_1 Education_2      Education_3
## Min.      :0.00000  Min.      :0      Min.      :0.0000  Min.      :0
## 1st Qu.:0.00000  1st Qu.:0      1st Qu.:0.0000  1st Qu.:0
## Median :0.00000  Median :0      Median :0.0000  Median :0
## Mean      :0.09167  Mean      :0      Mean      :0.4122  Mean      :0
## 3rd Qu.:0.00000  3rd Qu.:0      3rd Qu.:1.0000  3rd Qu.:0
## Max.      :1.00000  Max.      :0      Max.      :1.0000  Max.      :0

```

```
summary(Validation_Data)
```

```

## Personal.Loan      Education_1 Education_2      Education_3
## Min.      :0.00000  Min.      :0      Min.      :0.000  Min.      :0
## 1st Qu.:0.00000  1st Qu.:0      1st Qu.:0.000  1st Qu.:0
## Median :0.00000  Median :0      Median :0.000  Median :0
## Mean      :0.09417  Mean      :0      Mean      :0.425  Mean      :0
## 3rd Qu.:0.00000  3rd Qu.:0      3rd Qu.:1.000  3rd Qu.:0
## Max.      :1.00000  Max.      :0      Max.      :1.000  Max.      :0

```

```
summary(Test_Data)
```

```

## Personal.Loan      Education_1 Education_2      Education_3
## Min.      :0.000  Min.      :0      Min.      :0.000  Min.      :0
## 1st Qu.:0.000  1st Qu.:0      1st Qu.:0.000  1st Qu.:0
## Median :0.000  Median :0      Median :0.000  Median :0
## Mean      :0.101  Mean      :0      Mean      :0.422  Mean      :0
## 3rd Qu.:0.000  3rd Qu.:0      3rd Qu.:1.000  3rd Qu.:0
## Max.      :1.000  Max.      :0      Max.      :1.000  Max.      :0

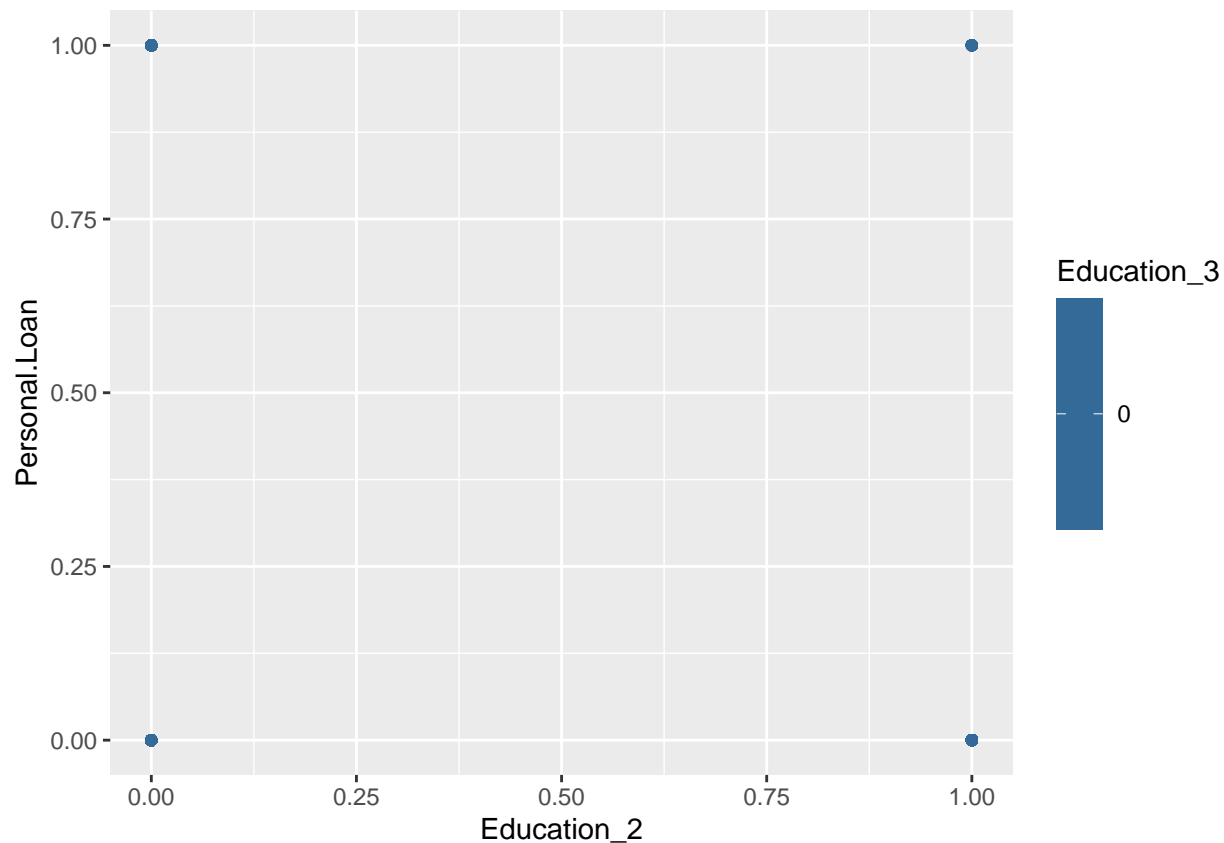
```

I now do the plotting

```

library(ggplot2)
ggplot(TraVal_Data,aes(x=Education_2,y=Personal.Loan,color=Education_3))+geom_point()

```



I now do the Normalization # I now follow the preProcess () function that is in the ‘caret’ package, the function implements min-max normalization using “range” as the method

```
# I Copy the original data
train.norm.df <- Train_Data
valid.norm.df <- Validation_Data
traval.norm.df <- TraVal_Data

# I use preProcess() from the caret package to normalize Personal Loan and Education.
norm.values <- preProcess(Train_Data[, c(1,3)], method=c("center", "scale"))

train.norm.df[, 1:4] <- predict(norm.values, Train_Data[, c(1,3)])# Replace first two columns with norm
valid.norm.df[, 1:4] <-predict(norm.values, Validation_Data[, 1:4])
traval.norm.df[, 1:4] <-predict(norm.values, traval.norm.df[, 1:4])
test.norm.df <- predict(norm.values, Test_Data[, 1:4])

summary(train.norm.df)
```

##	Personal.Loan	Education_1	Education_2	Education_3
##	Min. :-0.3176	Min. :-0.8372	Min. :-0.3176	Min. :-0.8372
##	1st Qu.:-0.3176	1st Qu.:-0.8372	1st Qu.:-0.3176	1st Qu.:-0.8372
##	Median :-0.3176	Median :-0.8372	Median :-0.3176	Median :-0.8372
##	Mean : 0.0000	Mean : 0.0000	Mean : 0.0000	Mean : 0.0000
##	3rd Qu.:-0.3176	3rd Qu.: 1.1938	3rd Qu.:-0.3176	3rd Qu.: 1.1938
##	Max. : 3.1470	Max. : 1.1938	Max. : 3.1470	Max. : 1.1938

```
var(train.norm.df[, 1:4])
```

```
##           Personal.Loan Education_1 Education_2 Education_3
## Personal.Loan      1.0000000 -0.1682533  1.0000000 -0.1682533
## Education_1       -0.1682533  1.0000000 -0.1682533  1.0000000
## Education_2        1.0000000 -0.1682533  1.0000000 -0.1682533
## Education_3       -0.1682533  1.0000000 -0.1682533  1.0000000
```

```
summary(valid.norm.df)
```

```
## Personal.Loan      Education_1 Education_2      Education_3
## Min.   :-0.317587  Min.   :0      Min.   :-0.83722  Min.   :0
## 1st Qu.:-0.317587  1st Qu.:0      1st Qu.:-0.83722  1st Qu.:0
## Median :-0.317587  Median :0      Median :-0.83722  Median :0
## Mean   : 0.008662  Mean   :0      Mean   : 0.02595  Mean   :0
## 3rd Qu.:-0.317587  3rd Qu.:0      3rd Qu.: 1.19377  3rd Qu.:0
## Max.    : 3.146996  Max.    :0      Max.    : 1.19377  Max.    :0
```

```
var(valid.norm.df[, 1:4])
```

```
##           Personal.Loan Education_1 Education_2 Education_3
## Personal.Loan      1.0247302          0 -0.1409945          0
## Education_1         0.0000000          0  0.0000000          0
## Education_2        -0.1409945          0  1.0088647          0
## Education_3         0.0000000          0  0.0000000          0
```

```
## Modeling K-NN
```

```
# I now applied knn. knn() which is available in library FNN (provides a list of the nearest neighbors)
```

```
``r
library(FNN)
nn <- knn(train = train.norm.df[, 1:4], test = test.norm.df,
          cl = train.norm.df[, 1], k = 1, prob=TRUE) # We use k = 1, and Education_1 is the Y
```

```
# print(nn) # uncomment for more output
```

```
row.names(Train_Data)[attr(nn, "nn.index")]
```

```
##      [1] "4552" "2552" "2552" "2552" "2552" "4552" "4552" "4552" "2552" "2552"
##     [11] "4552" "2552" "2552" "2552" "4552" "4552" "2552" "2552" "4552" "2552"
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## [651] "2552" "2552" "2552" "2552" "2552" "2552" "2552" "4552" "4552" "4440"

```

##	[661]	"2552"	"2552"	"2552"	"2552"	"2552"	"2552"	"4552"	"2552"	"4552"	"4552"
##	[671]	"2552"	"2552"	"2552"	"2552"	"2552"	"4552"	"2552"	"2552"	"4552"	"2552"
##	[681]	"2552"	"2552"	"4552"	"2552"	"2552"	"4552"	"2552"	"2552"	"2552"	"2552"
##	[691]	"2552"	"2552"	"4552"	"4552"	"4552"	"2552"	"2552"	"2552"	"4552"	"2552"
##	[701]	"2552"	"2552"	"4552"	"4552"	"2552"	"4552"	"2552"	"4552"	"2552"	"2552"
##	[711]	"4552"	"2552"	"4552"	"2552"	"4552"	"2552"	"2552"	"2552"	"2552"	"2552"
##	[721]	"4552"	"4552"	"2552"	"4552"	"4552"	"2552"	"4552"	"2552"	"4552"	"4552"
##	[731]	"4552"	"2552"	"2552"	"4552"	"4552"	"2552"	"4552"	"2552"	"4552"	"2552"
##	[741]	"4440"	"2552"	"4552"	"4552"	"2552"	"4552"	"2552"	"2552"	"4552"	"4552"
##	[751]	"4552"	"4552"	"2552"	"2552"	"2552"	"2552"	"4552"	"4552"	"4552"	"4552"
##	[761]	"4552"	"2552"	"2552"	"2552"	"2552"	"4552"	"2552"	"2552"	"2552"	"4552"
##	[771]	"4440"	"4552"	"4552"	"2552"	"4552"	"2552"	"4552"	"4552"	"4440"	"4552"
##	[781]	"2552"	"4552"	"2552"	"4552"	"2552"	"4552"	"2552"	"2552"	"2552"	"4552"
##	[791]	"2552"	"2552"	"2552"	"4552"	"2552"	"4552"	"2552"	"2552"	"2552"	"4552"
##	[801]	"2552"	"4552"	"2552"	"4552"	"2552"	"4552"	"4552"	"4552"	"4552"	"4552"
##	[811]	"2552"	"2552"	"2552"	"4552"	"2552"	"2552"	"4552"	"2552"	"2552"	"4552"
##	[821]	"2552"	"2552"	"2552"	"4552"	"4552"	"2552"	"2552"	"2552"	"2552"	"2552"
##	[831]	"2552"	"4552"	"4552"	"4440"	"2552"	"2552"	"4552"	"2552"	"2552"	"2552"
##	[841]	"2552"	"2552"	"2552"	"4552"	"4552"	"4552"	"4552"	"4552"	"2552"	"4552"
##	[851]	"4552"	"2552"	"4552"	"4552"	"2552"	"2552"	"2552"	"2552"	"4552"	"2552"
##	[861]	"4552"	"2552"	"2552"	"4552"	"2552"	"4552"	"2552"	"4552"	"4552"	"2552"
##	[871]	"2552"	"2552"	"4552"	"2552"	"4552"	"4552"	"4552"	"2552"	"2552"	"4552"
##	[881]	"4552"	"2552"	"2552"	"4552"	"2552"	"4552"	"4440"	"2552"	"2552"	"2552"
##	[891]	"2552"	"4552"	"4552"	"4552"	"2552"	"2552"	"2552"	"2552"	"4552"	"4552"
##	[901]	"2552"	"4552"	"4552"	"2552"	"4552"	"4552"	"2552"	"4552"	"2552"	"2552"
##	[911]	"2552"	"2552"	"2552"	"2552"	"4552"	"2552"	"2552"	"2552"	"4552"	"4552"
##	[921]	"2552"	"4552"	"4552"	"2552"	"2552"	"2552"	"4552"	"2552"	"4552"	"4552"
##	[931]	"2552"	"2552"	"4552"	"4552"	"2552"	"4552"	"4552"	"4440"	"2552"	"4552"
##	[941]	"2552"	"2552"	"4552"	"2552"	"2552"	"4552"	"2552"	"4552"	"2552"	"4552"
##	[951]	"2552"	"2552"	"2552"	"4552"	"4552"	"4552"	"4552"	"4440"	"2552"	"2552"
##	[961]	"2552"	"2552"	"2552"	"2552"	"2552"	"2552"	"2552"	"2552"	"4552"	"4552"
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##	[981]	"4552"	"4552"	"2552"	"2552"	"2552"	"4440"	"2552"	"2552"	"4552"	"4552"
##	[991]	"2552"	"2552"	"4552"	"2552"	"2552"	"4552"	"2552"	"2552"	"2552"	"2552"
##	[1001]	"4552"	"2552"	"4552"	"2552"	"2552"	"2552"	"2552"	"2552"	"2552"	"4552"
##	[1011]	"2552"	"2552"	"2552"	"4552"	"2552"	"4552"	"2552"	"2552"	"2552"	"2552"
##	[1021]	"4552"	"2552"	"4552"	"4552"	"2552"	"4552"	"2552"	"4552"	"2552"	"4552"
##	[1031]	"2552"	"2552"	"4552"	"4552"	"2552"	"2552"	"2552"	"4552"	"4552	

##	[1201]	"4552"	"2552"	"4552"	"2552"	"2552"	"2552"	"2552"	"2552"	"2552"
##	[1211]	"2552"	"2552"	"4552"	"4440"	"2552"	"2552"	"4552"	"4552"	"4552"
##	[1221]	"2552"	"4552"	"4552"	"2552"	"2552"	"4440"	"2552"	"4552"	"2552"
##	[1231]	"4552"	"2552"	"4552"	"2552"	"2552"	"4552"	"2552"	"4552"	"2552"
##	[1241]	"4552"	"2552"	"2552"	"2552"	"2552"	"4552"	"4552"	"2552"	"4552"
##	[1251]	"2552"	"2552"	"4552"	"2552"	"2552"	"2552"	"2552"	"2552"	"2552"
##	[1261]	"4552"	"2552"	"4552"	"2552"	"2552"	"4552"	"2552"	"2552"	"4552"
##	[1271]	"2552"	"2552"	"4552"	"2552"	"2552"	"2552"	"2552"	"4552"	"2552"
##	[1281]	"4552"	"4552"	"4440"	"4552"	"2552"	"2552"	"2552"	"2552"	"4552"
##	[1291]	"2552"	"4552"	"4552"	"4552"	"2552"	"2552"	"2552"	"4552"	"4552"
##	[1301]	"2552"	"2552"	"4552"	"2552"	"4552"	"2552"	"4552"	"2552"	"4552"
##	[1311]	"4552"	"4552"	"4552"	"2552"	"2552"	"2552"	"2552"	"4552"	"2552"
##	[1321]	"2552"	"2552"	"2552"	"2552"	"2552"	"2552"	"4552"	"2552"	"2552"
##	[1331]	"2552"	"4552"	"4552"	"2552"	"2552"	"2552"	"4552"	"4552"	"2552"
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```

Hypertuning using Validation

```
# To determine k, we use the performance on the validation set.
#Here, we will vary the value of k from 1 to 14
```

```
# I initialize a data frame with two columns: k, and accuracy.
#library(caret)
#accuracy.df <- data.frame(k = seq(1, 14, 1), accuracy = rep(0, 14))
# compute knn for different k on validation.
#for(i in 1:14) {
#   knn.pred <- knn(train.norm.df[, 1:2], valid.norm.df[, 1:2],
#                   cl = train.norm.df[, 3], k = i)
#   accuracy.df[i, 2] <- confusionMatrix(knn.pred, valid.norm.df[, 3])$overall[1]
#}
#accuracy.df

# the optimal K is 3
```

Prediction

```
``r
library(caret)
library(lattice)
library(ggplot2)
```

```
library(ISLR)
```

```
norm.values<-preProcess(TraVal_Data[, c(1,3)], method=c("center", "scale")) # Use combined set to norma
traval.norm.df[, 1:2] <- predict(norm.values, TraVal_Data[, c(1,3)])
test.norm.df[, 1:2] <- predict(norm.values, Test_Data[, c(1,3)])
summary(traval.norm.df)
```

```
## Personal.Loan      Education_1      Education_2      Education_3
## Min.      :-0.3195  Min.      :-0.8462  Min.      :-0.83722  Min.      :0
## 1st Qu.   :-0.3195  1st Qu.   :-0.8462  1st Qu.   :-0.83722  1st Qu.   :0
## Median    :-0.3195  Median    :-0.8462  Median    :-0.83722  Median    :0
## Mean      : 0.0000  Mean      : 0.0000  Mean      : 0.01038  Mean      :0
## 3rd Qu.   :-0.3195  3rd Qu.   : 1.1814  3rd Qu.   : 1.19377  3rd Qu.   :0
## Max.      : 3.1286  Max.      : 1.1814  Max.      : 1.19377  Max.      :0
```

```
summary(test.norm.df)
```

```
## Personal.Loan      Education_1      Education_2      Education_3
## Min.      :-0.31953  Min.      :-0.846173  Min.      :-0.83722  Min.      :0
## 1st Qu.   :-0.31953  1st Qu.   :-0.846173  1st Qu.   :-0.83722  1st Qu.   :0
## Median    :-0.31953  Median    :-0.846173  Median    :-0.83722  Median    :0
## Mean      : 0.02873  Mean      : 0.009462  Mean      : 0.01986  Mean      :0
## 3rd Qu.   :-0.31953  3rd Qu.   : 1.181398  3rd Qu.   : 1.19377  3rd Qu.   :0
## Max.      : 3.12859  Max.      : 1.181398  Max.      : 1.19377  Max.      :0
```

Now we predict for the test set.

```
library(caret)
```

```
knn.pred.new<-knn(traval.norm.df[, 1:4], test.norm.df, cl = traval.norm.df[, 4], k = 3)
row.names(TraVal_Data)[attr(nn, "nn.index")]
```

```
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##	[861]	"2762"	"1576"	"1576"	"2762"	"1576"	"2762"	"1576"	"2762"	"2762"	"1576"
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##	[881]	"2762"	"1576"	"1576"	"2762"	"1576"	"2762"	"2692"	"1576"	"1576"	"1576"
##	[891]	"1576"	"2762"	"2762"	"2762"	"1576"	"1576"	"1576"	"1576"	"2762"	"2762"
##	[901]	"1576"	"2762"	"2762"	"1576"	"2762"	"2762"	"1576"	"2762"	"1576"	"1576"
##	[911]	"1576"	"1576"	"1576"	"1576"	"2762"	"1576"	"1576"	"1576"	"2762"	"2762"
##	[921]	"1576"	"2762"	"2762"	"1576"	"1576"	"1576"	"2762"	"1576"	"2762"	"2762"
##	[931]	"1576"	"1576"	"2762"	"2762"	"1576"	"2762"	"2762"	"2692"	"1576"	"2762"
##	[941]	"1576"	"1576"	"2762"	"1576"	"1576"	"2762"	"1576"	"2762"	"1576"	"2762"
##	[951]	"1576"	"1576"	"1576"	"2762"	"2762"	"2762"	"2762"	"2692"	"1576"	"1576"
##	[961]	"1576"	"1576"	"1576"	"1576"	"1576"	"1576"	"1576"	"1576"	"2762"	"2762"
##	[971]	"2762"	"1576"	"1576"	"2762"	"1576"	"1576"	"1576"	"2762"	"1576"	"2762"
##	[981]	"2762"	"2762"	"1576"	"1576"	"1576"	"2692"	"1576"	"1576"	"2762"	"2762"
##	[991]	"1576"	"1576"	"2762"	"1576"	"1576"	"2762"	"1576"	"1576"	"1576"	"1576"
##	[1001]	"2762"	"1576"	"2762"	"1576"	"1576"	"1576"	"1576"	"1576"	"1576"	"2762"
##	[1011]	"1576"	"1576"	"1576"	"2762"	"1576"	"2762"	"1576"	"1576"	"1576"	"1576"
##	[1021]	"2762"	"1576"	"2762"	"2762"	"1576"	"2762"	"1576"	"2762"	"1576"	"2762"
##	[1031]	"1576"	"1576"	"2762"	"2762"	"1576"	"1576"	"1576"	"2762"	"2762"	"1576"
##	[1041]	"1576"	"2692"	"2762"	"1576"	"1576"	"2762"	"2762"	"1576"	"1576"	"1576"
##	[1051]	"1576"	"2762"	"2762"	"1576"	"1576"	"1576"	"2762"	"1576"	"1576"	"2692"
##	[1061]	"1576"	"2762"	"1576"	"1576"	"2762"	"1576"	"2762"	"2762"	"1576"	"1576"
##	[1071]	"2762"	"1576"	"1576"	"2762"	"1576"	"1576"	"1576"	"2762"	"1576"	"1576"
##	[1081]	"2762"	"1576"	"2762"	"2762"	"1576"	"1576"	"2762"	"1576"		

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[1271] "1576" "1576" "2762" "1576" "1576" "1576" "1576" "2762" "2762" "1576"
[1281] "2762" "2762" "2692" "2762" "1576" "1576" "1576" "1576" "2762" "1576"
[1291] "1576" "2762" "2762" "2762" "1576" "1576" "1576" "2762" "2762" "2762"
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[1321] "1576" "1576" "1576" "1576" "1576" "1576" "2762" "1576" "1576" "1576"
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[1391] "1576" "1576" "1576" "2762" "1576" "1576" "2762" "2762" "2762" "1576"
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[1421] "1576" "1576" "2692" "1576" "1576" "2762" "1576" "1576" "2762" "1576"
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[1441] "1576" "2762" "2692" "1576" "1576" "2762" "1576" "1576" "2762" "2762"
[1451] "1576" "1576" "1576" "1576" "2762" "1576" "1576" "1576" "1576" "1576"
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[1541] "2762" "1576" "2762" "1576" "1576" "2762" "1576" "2762" "2762" "2762"
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[1581] "1576" "1576" "1576" "2762" "1576" "1576" "2762" "1576" "2762" "1576"
[1591] "2762" "1576" "1576" "2762" "1576" "1576" "1576" "1576" "1576" "1576"
[1601] "1576" "2762" "1576" "1576" "2762" "1576" "2762" "1576" "1576" "1576"
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[1641] "1576" "1576" "1576" "1576" "1576" "1576" "2762" "1576" "2762" "1576"
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[1681] "2762" "2762" "1576" "1576" "1576" "2692" "2762" "2762" "1576" "1576"
[1691] "1576" "1576" "2762" "1576" "1576" "1576" "1576" "1576" "1576" "2762"
[1701] "1576" "1576" "1576" "1576" "1576" "1576" "2762" "2762" "1576" "1576"
[1711] "2762" "2762" "1576" "1576" "1576" "1576" "2762" "1576" "1576" "1576"
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[1741] "2762" "2762" "1576" "2762" "2762" "2762" "1576" "1576" "1576" "2762"
[1751] "2692" "1576" "2762" "1576" "1576" "1576" "2762" "1576" "1576" "1576"
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[1771] "1576" "1576" "1576" "2762" "2692" "2762" "1576" "1576" "1576" "2762"
[1781] "1576" "2762" "1576" "1576" "1576" "2762" "2762" "2762" "1576" "1576"

```
## [1791] "2762" "2762" "1576" "2762" "1576" "1576" "2762" "1576" "2762" "1576"
## [1801] "1576" "2762" "1576" "2762" "1576" "1576" "2762" "1576" "1576" "1576"
## [1811] "2762" "2762" "1576" "1576" "2762" "1576" "1576" "1576" "1576" "2762"
## [1821] "1576" "1576" "2762" "1576" "2762" "1576" "2762" "2762" "1576" "1576"
## [1831] "1576" "1576" "1576" "1576" "2762" "2762" "1576" "1576" "1576" "1576"
## [1841] "1576" "1576" "1576" "1576" "1576" "1576" "1576" "1576" "1576" "1576"
## [1851] "2762" "1576" "2762" "1576" "1576" "1576" "2762" "1576" "1576" "2762"
## [1861] "1576" "1576" "1576" "1576" "2762" "1576" "1576" "1576" "2762" "1576"
## [1871] "2762" "2692" "1576" "2762" "2762" "1576" "1576" "1576" "1576" "2762"
## [1881] "1576" "2762" "2762" "1576" "1576" "1576" "1576" "1576" "2692" "1576"
## [1891] "2692" "2762" "2762" "2762" "1576" "2762" "2762" "1576" "2762" "2762"
## [1901] "2762" "1576" "2762" "1576" "1576" "1576" "2762" "1576" "1576" "2762"
## [1911] "1576" "2762" "2762" "1576" "2762" "2762" "2762" "2762" "1576" "1576"
## [1921] "1576" "1576" "1576" "2762" "1576" "2762" "1576" "1576" "2762" "2762"
## [1931] "2762" "2762" "1576" "1576" "2762" "1576" "1576" "2762" "1576" "2762"
## [1941] "1576" "1576" "2762" "1576" "1576" "2762" "2762" "2762" "2762" "2762"
## [1951] "2762" "2762" "1576" "2762" "1576" "2762" "1576" "1576" "1576" "1576"
## [1961] "2762" "2762" "1576" "2762" "1576" "2762" "1576" "1576" "2762" "2762"
## [1971] "2762" "1576" "1576" "2762" "1576" "2762" "1576" "1576" "2762" "2762"
## [1981] "1576" "1576" "2762" "1576" "2762" "1576" "1576" "1576" "1576" "1576"
## [1991] "1576" "1576" "1576" "2692" "2762" "2762" "2762" "1576" "1576" "2762"
```

Partitioning the data into 50%, 30%, and 20%

```
library(dplyr)
m_Assignment2_UpdateNew <-select(Assignment2_UpdateNew,Personal.Loan,Education_1,Education_2,
Education_3) #Select a subset of variables

set.seed(15)
Test_Index = createDataPartition(m_Assignment2_UpdateNew$Personal.Loan,p=0.2, list=FALSE) # 20% reserve
Test_Data = m_Assignment2_UpdateNew[Test_Index,]
TraVal_Data = m_Assignment2_UpdateNew[-Test_Index,] # Validation and Training data is rest

Train_Index = createDataPartition(TraVal_Data$Personal.Loan,p=0.50, list=FALSE) # 50% of remaining data
Train_Data = TraVal_Data[Train_Index,]
Validation_Data = TraVal_Data[-Train_Index,] # rest as validation

summary(TraVal_Data)
```

```
## Personal.Loan      Education_1 Education_2      Education_3
## Min.   :0.0000   Min.   :0   Min.   :0.000   Min.   :0
## 1st Qu.:0.0000   1st Qu.:0   1st Qu.:0.000   1st Qu.:0
## Median :0.0000   Median :0   Median :0.000   Median :0
## Mean   :0.0905   Mean   :0   Mean   :0.415   Mean   :0
## 3rd Qu.:0.0000   3rd Qu.:0   3rd Qu.:1.000   3rd Qu.:0
## Max.   :1.0000   Max.   :0   Max.   :1.000   Max.   :0
```

```
summary(Validation_Data)
```

```
## Personal.Loan      Education_1 Education_2      Education_3
```

```
## Min.      :0.0000   Min.      :0   Min.      :0.000   Min.      :0
## 1st Qu.:0.0000   1st Qu.:0   1st Qu.:0.000   1st Qu.:0
## Median :0.0000   Median :0   Median :0.000   Median :0
## Mean    :0.1015   Mean     :0   Mean     :0.423   Mean     :0
## 3rd Qu.:0.0000   3rd Qu.:0   3rd Qu.:1.000   3rd Qu.:0
## Max.     :1.0000   Max.      :0   Max.      :1.000   Max.      :0
```

```
summary(Test_Data)
```

```
## Personal.Loan   Education_1 Education_2   Education_3
## Min.      :0.000   Min.      :0   Min.      :0.00   Min.      :0
## 1st Qu.:0.000   1st Qu.:0   1st Qu.:0.00   1st Qu.:0
## Median :0.000   Median :0   Median :0.00   Median :0
## Mean     :0.096   Mean     :0   Mean     :0.42   Mean     :0
## 3rd Qu.:0.000   3rd Qu.:0   3rd Qu.:1.00   3rd Qu.:0
## Max.     :1.000   Max.      :0   Max.      :1.00   Max.      :0
```

```
# Creating Dummy Variables for Categorical Variables
```

One approach to calculate distances for categorical variables is to first convert them to numeric using

```
```r
levels(Carseats$US)
```

```
[1] "No" "Yes"
```

```
dummy_model <- dummyVars(~US,data=Carseats)
head(predict(dummy_model,Carseats))
```

```
US.No US.Yes
1 0 1
2 0 1
3 0 1
4 0 1
5 1 0
6 0 1
```

---

## Hypertuning - kNN - Part 2

Earlier, we saw an example of hypertuning in determining the value of  $k$ . Small values, while sensitive to the data, may also model noise, while large values of  $k$  leads to smoother predictions, but are insensitive to local changes. We also saw an example above on how to pick  $k$  using the validation set results.

Here, we will use the *Caret* package that provides a wrapper for a large number of machine learning models (more than 200 models as of now). The `train()` function will automatically perform a grid search over a pre-defined set of hyperparameter values. It then select the best hyperparameter values, for us,  $k$ , using cross validations and train a model. This makes the process easier.

## Example - Hypertuning

```
library(ISLR)
library(caret)
#Default dataset is a part of the ISLR package
It captures credit card default status as well as balance, income, and student status
summary(Assignment2_UpdateNew)
```

```
Age Experience Income Family
Min. :23.00 Min. : -3.0 Min. : 8.00 Min. :1.000
1st Qu.:35.00 1st Qu.:10.0 1st Qu.: 39.00 1st Qu.:1.000
Median :45.00 Median :20.0 Median : 64.00 Median :2.000
Mean :45.34 Mean :20.1 Mean : 73.77 Mean :2.396
3rd Qu.:55.00 3rd Qu.:30.0 3rd Qu.: 98.00 3rd Qu.:3.000
Max. :67.00 Max. :43.0 Max. :224.00 Max. :4.000
CCAvg Education_1 Education_2 Education_3 Mortgage
Min. : 0.000 Min. :0 Min. :0.0000 Min. :0 Min. : 0.0
1st Qu.: 0.700 1st Qu.:0 1st Qu.:0.0000 1st Qu.:0 1st Qu.: 0.0
Median : 1.500 Median :0 Median :0.0000 Median :0 Median : 0.0
Mean : 1.938 Mean :0 Mean :0.4192 Mean :0 Mean : 56.5
3rd Qu.: 2.500 3rd Qu.:0 3rd Qu.:1.0000 3rd Qu.:0 3rd Qu.:101.0
Max. :10.000 Max. :0 Max. :1.0000 Max. :0 Max. :635.0
Personal.Loan Securities.Account CD.Account Online
Min. :0.000 Min. :0.0000 Min. :0.0000 Min. :0.0000
1st Qu.:0.000 1st Qu.:0.0000 1st Qu.:0.0000 1st Qu.:0.0000
Median :0.000 Median :0.0000 Median :0.0000 Median :1.0000
Mean :0.096 Mean :0.1044 Mean :0.0604 Mean :0.5968
3rd Qu.:0.000 3rd Qu.:0.0000 3rd Qu.:0.0000 3rd Qu.:1.0000
Max. :1.000 Max. :1.0000 Max. :1.0000 Max. :1.0000
CreditCard
Min. :0.000
1st Qu.:0.000
Median :0.000
Mean :0.294
3rd Qu.:1.000
Max. :1.000
```

## Normalization

```
#let's normalize the data before modelling
norm_model<-preProcess(Assignment2_UpdateNew, method = c('range')) # We are using range here, but we can
```

```
Warning in preProcess.default(Assignment2_UpdateNew, method = c("range")): No
variation for for: Education_1, Education_3
```

```
Default_normalized<-predict(norm_model,Assignment2_UpdateNew)
summary(Default_normalized)
```

```
Age Experience Income Family
```

```
Min. :0.0000 Min. :0.0000 Min. :0.0000 Min. :0.0000
1st Qu.:0.2727 1st Qu.:0.2826 1st Qu.:0.1435 1st Qu.:0.0000
Median :0.5000 Median :0.5000 Median :0.2593 Median :0.3333
Mean :0.5077 Mean :0.5023 Mean :0.3045 Mean :0.4655
3rd Qu.:0.7273 3rd Qu.:0.7174 3rd Qu.:0.4167 3rd Qu.:0.6667
Max. :1.0000 Max. :1.0000 Max. :1.0000 Max. :1.0000
CCAvg Education_1 Education_2 Education_3 Mortgage
Min. :0.0000 Min. :0 Min. :0.0000 Min. :0 Min. :0.00000
1st Qu.:0.0700 1st Qu.:0 1st Qu.:0.0000 1st Qu.:0 1st Qu.:0.00000
Median :0.1500 Median :0 Median :0.0000 Median :0 Median :0.00000
Mean :0.1938 Mean :0 Mean :0.4192 Mean :0 Mean :0.08897
3rd Qu.:0.2500 3rd Qu.:0 3rd Qu.:1.0000 3rd Qu.:0 3rd Qu.:0.15906
Max. :1.0000 Max. :0 Max. :1.0000 Max. :0 Max. :1.00000
Personal.Loan Securities.Account CD.Account Online
Min. :0.000 Min. :0.0000 Min. :0.0000 Min. :0.0000
1st Qu.:0.000 1st Qu.:0.0000 1st Qu.:0.0000 1st Qu.:0.0000
Median :0.000 Median :0.0000 Median :0.0000 Median :1.0000
Mean :0.096 Mean :0.1044 Mean :0.0604 Mean :0.5968
3rd Qu.:0.000 3rd Qu.:0.0000 3rd Qu.:0.0000 3rd Qu.:1.0000
Max. :1.000 Max. :1.0000 Max. :1.0000 Max. :1.0000
CreditCard
Min. :0.000
1st Qu.:0.000
Median :0.000
Mean :0.294
3rd Qu.:1.000
Max. :1.000
```

```
sd(Default_normalized$Education_2)
```

```
[1] 0.4934775
```

As we use the range for normalizing, the mean and variances are not 0, and 1 respectively.

## train

let's train a k-NN model using the train() function from Caret

```
By setting the random seed, we can reproduce the results
set.seed(123)
model<-train(Personal.Loan~Age, data=Default_normalized, method="knn")
```

```
Warning in train.default(x, y, weights = w, ...): You are trying to do
regression and your outcome only has two possible values Are you trying to do
classification? If so, use a 2 level factor as your outcome column.
```

```
model
```

```
k-Nearest Neighbors
##
5000 samples
1 predictor
##
No pre-processing
Resampling: Bootstrapped (25 reps)
Summary of sample sizes: 5000, 5000, 5000, 5000, 5000, 5000, ...
Resampling results across tuning parameters:
##
k RMSE Rsquared MAE
5 0.2972049 0.0006986014 0.1739488
7 0.2972049 0.0006986014 0.1739488
9 0.2972049 0.0006986014 0.1739488
##
RMSE was used to select the optimal model using the smallest value.
The final value used for the model was k = 9.
```

## Customizing the search grid

Let us now customize the search space for k

```
set.seed(123)
Search_grid <- expand.grid(k=c(2,7,9,15))
model<-train(Personal.Loan~Age, data=Default_normalized,
 method="knn", tuneGrid=Search_grid)
```

```
Warning in train.default(x, y, weights = w, ...): You are trying to do
regression and your outcome only has two possible values Are you trying to do
classification? If so, use a 2 level factor as your outcome column.
```

```
model
```

```
k-Nearest Neighbors
##
5000 samples
1 predictor
##
No pre-processing
Resampling: Bootstrapped (25 reps)
Summary of sample sizes: 5000, 5000, 5000, 5000, 5000, 5000, ...
Resampling results across tuning parameters:
##
k RMSE Rsquared MAE
2 0.2972049 0.0006986014 0.1739488
7 0.2972049 0.0006986014 0.1739488
9 0.2972049 0.0006986014 0.1739488
15 0.2972409 0.0006485694 0.1740740
##
RMSE was used to select the optimal model using the smallest value.
The final value used for the model was k = 9.
```



We have now restricted the search for the optimal k based on our search space. Finally, let us incorporate all aspects, preprocessing, train, and search in one function

---

## Final Function

```
set.seed(123)
Search_grid <- expand.grid(k=c(2,7,9,15))
model<-train(Personal.Loan~Age+Education_2, data=Assignment2_UpdateNew,
 method="knn", tuneGrid=Search_grid,
 preProcess='range')
```

```
Warning in train.default(x, y, weights = w, ...): You are trying to do
regression and your outcome only has two possible values Are you trying to do
classification? If so, use a 2 level factor as your outcome column.
```

```
model
```

```
k-Nearest Neighbors
##
5000 samples
2 predictor
##
Pre-processing: re-scaling to [0, 1] (2)
Resampling: Bootstrapped (25 reps)
Summary of sample sizes: 5000, 5000, 5000, 5000, 5000, ...
Resampling results across tuning parameters:
##
k RMSE Rsquared MAE
2 0.2962475 0.01103495 0.1703172
7 0.2962981 0.01090184 0.1704811
9 0.2963489 0.01075425 0.1706443
15 0.2964586 0.01039223 0.1710571
##
RMSE was used to select the optimal model using the smallest value.
The final value used for the model was k = 2.
```

---

## k-NN Class Package

```
#install.packages("Class") #install first if needed
library(class)
```

```
##
Attaching package: 'class'
```

```
The following objects are masked from 'package:FNN':
##
knn, knn.cv
```

```
library(caret)
library(ISLR)

summary(Assignment2_UpdateNew)
```

```
Age Experience Income Family
Min. :23.00 Min. : -3.0 Min. : 8.00 Min. :1.000
1st Qu.:35.00 1st Qu.:10.0 1st Qu.: 39.00 1st Qu.:1.000
Median :45.00 Median :20.0 Median : 64.00 Median :2.000
Mean :45.34 Mean :20.1 Mean : 73.77 Mean :2.396
3rd Qu.:55.00 3rd Qu.:30.0 3rd Qu.: 98.00 3rd Qu.:3.000
Max. :67.00 Max. :43.0 Max. :224.00 Max. :4.000
CCAvg Education_1 Education_2 Education_3 Mortgage
Min. : 0.000 Min. :0 Min. :0.0000 Min. :0 Min. : 0.0
1st Qu.: 0.700 1st Qu.:0 1st Qu.:0.0000 1st Qu.:0 1st Qu.: 0.0
Median : 1.500 Median :0 Median :0.0000 Median :0 Median : 0.0
Mean : 1.938 Mean :0 Mean :0.4192 Mean :0 Mean : 56.5
3rd Qu.: 2.500 3rd Qu.:0 3rd Qu.:1.0000 3rd Qu.:0 3rd Qu.:101.0
Max. :10.000 Max. :0 Max. :1.0000 Max. :0 Max. :635.0
Personal.Loan Securities.Account CD.Account Online
Min. :0.000 Min. :0.0000 Min. :0.0000 Min. :0.0000
1st Qu.:0.000 1st Qu.:0.0000 1st Qu.:0.0000 1st Qu.:0.0000
Median :0.000 Median :0.0000 Median :0.0000 Median :1.0000
Mean :0.096 Mean :0.1044 Mean :0.0604 Mean :0.5968
3rd Qu.:0.000 3rd Qu.:0.0000 3rd Qu.:0.0000 3rd Qu.:1.0000
Max. :1.000 Max. :1.0000 Max. :1.0000 Max. :1.0000
CreditCard
Min. :0.000
1st Qu.:0.000
Median :0.000
Mean :0.294
3rd Qu.:1.000
Max. :1.000
```

Let us now normalize the data

```
#normalize the data first: build a model and apply
norm_model<-preProcess(Assignment2_UpdateNew, method = c('range'))
```

```
Warning in preProcess.default(Assignment2_UpdateNew, method = c("range")): No
variation for for: Education_1, Education_3
```

```
Default_normalized<-predict(norm_model,Assignment2_UpdateNew)
```

We now predict Default using income and balance

```
Default_normalized<-Default_normalized[,-2]
Use 50% of data for training and the rest for testing
Index_Train<-createDataPartition(Default_normalized$Personal.Loan, p=0.5, list=FALSE)
Train <-Default_normalized[Index_Train,]
Test <-Default_normalized[-Index_Train,]
```

The Y variable is Default (first column), which is Yes, or No. Second and third columns are normalized “balance” and “income”

```
Train_Predictors<-Train[,c(1,2,3,7)]
Test_Predictors<-Test[,c(1,2,3,7)]
Train_labels <-Train[,10]
Test_labels <-Test[,10]
```

Train a knn model where k=9

```
Predicted_Test_labels <-knn(Train_Predictors,
 Test_Predictors,
 cl=Train_labels,
 k=9)
Look at the 6 first values of predicted class (i.e., default status) of test set
head(Predicted_Test_labels)
```

```
[1] 0 0 0 0 0 0
Levels: 0 1
```

---

## Confusion Matrix

We can print out the confusion matrix, which is part of the CrossTable() function in the “gmodels” package

```
#install.packages("gmodels") # install if necessary
library("gmodels")
CrossTable(x=Test_labels,y=Predicted_Test_labels, prop.chisq = FALSE)
```

```
##
##
Cell Contents
|-----|
| N |
| N / Row Total |
| N / Col Total |
| N / Table Total |
|-----|
##
##
Total Observations in Table: 2500
##
##
```

```
| Predicted_Test_labels
Test_labels | 0 | 1 | Row Total |
-----|-----|-----|-----|
0 | 2232 | 1 | 2233 |
| 1.000 | 0.000 | 0.893 |
| 0.893 | 1.000 | |
| 0.893 | 0.000 | |
-----|-----|-----|-----|
1 | 267 | 0 | 267 |
| 1.000 | 0.000 | 0.107 |
| 0.107 | 0.000 | |
| 0.107 | 0.000 | |
-----|-----|-----|-----|
Column Total | 2499 | 1 | 2500 |
| 1.000 | 0.000 | |
-----|-----|-----|-----|
##
##
```

This matrix shows the following: If Yes is positive, then the misclassifications are 27 false positives, and 43 false negatives. We can identify several measures based on this table. For example

- Accuracy = Number correctly identified / Total =  $(23 + 1906) / 1999 = .965$
- Recall is the true positive rate or sensitivity =  $23 / 66 = .348$
- Precision is the positive predictive value =  $23 / (23 + 27) = 0.460$
- Specificity, also called as the true negative rate =  $1906 / 1933 = .986$

In simple terms, high precision means that an algorithm returned substantially more relevant (positive) results than irrelevant (negative) ones, while high recall means that an algorithm returned most of the relevant (positive) results.

To find the proportion, look at the proportion across row. For example, false positive is the algorithm labelling a No as Yes, or in other words  $P(\text{Yes} | \text{No}) = 27 / 1933 = 0.014$ . Similarly, false negative is the algorithm labelling a Yes as a No, or  $P(\text{No} | \text{Yes}) = 43 / 66 = 0.652$ .

## Probability Output

Sometimes, it is preferred to have raw prediction probabilities rather than predicted class labels. `knn()` can additionally return probabilities if 'prob' argument is set to true. The probability is defined as the proportion of nearest neighbors that belongs to the majority class. For example, the probability will be 0.6 if 3 out of 5 nearest neighbors are from one class.

```
Predicted_Test_labels <-knn(Train_Predictors,
 Test_Predictors,
 cl=Train_labels, k=100, prob=TRUE)
class_prob<-attr(Predicted_Test_labels, 'prob')
head(class_prob)
```

```
[1] 0.8600000 0.9300000 0.8500000 0.9000000 0.8613861 0.9504950
```