Assignment 2 Kerrie Mars

Kerrie Mars

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## R Markdown

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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:

#clear existing data in Environment  
rm(list=ls())  
#load data  
bank.df <- read.csv("UniversalBank.csv", header = TRUE)  
#find dimension of data frame  
dim(bank.df)

## [1] 5000 14

#open libraries  
library(ISLR)

## Warning: package 'ISLR' was built under R version 4.1.3

library(forecast) #for evaluating performance

## Warning: package 'forecast' was built under R version 4.1.3

## Registered S3 method overwritten by 'quantmod':  
## method from  
## as.zoo.data.frame zoo

library(class) #for allowing a numerical output variable

## Warning: package 'class' was built under R version 4.1.3

library(psych) #for creating dummies

## Warning: package 'psych' was built under R version 4.1.3

library(caret) #for data partition, normalize data

## Warning: package 'caret' was built under R version 4.1.3

## Loading required package: ggplot2

## Warning: package 'ggplot2' was built under R version 4.1.3

##   
## Attaching package: 'ggplot2'

## The following objects are masked from 'package:psych':  
##   
## %+%, alpha

## Loading required package: lattice

library(FNN) #for Performing knn classification

## Warning: package 'FNN' was built under R version 4.1.3

##   
## Attaching package: 'FNN'

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

#show all the data in a new tab  
View(bank.df)  
  
#find summary statistics for each column  
summary(bank.df)

## ID Age Experience Income ZIP.Code   
## Min. : 1 Min. :23.00 Min. :-3.0 Min. : 8.00 Min. : 9307   
## 1st Qu.:1251 1st Qu.:35.00 1st Qu.:10.0 1st Qu.: 39.00 1st Qu.:91911   
## Median :2500 Median :45.00 Median :20.0 Median : 64.00 Median :93437   
## Mean :2500 Mean :45.34 Mean :20.1 Mean : 73.77 Mean :93153   
## 3rd Qu.:3750 3rd Qu.:55.00 3rd Qu.:30.0 3rd Qu.: 98.00 3rd Qu.:94608   
## Max. :5000 Max. :67.00 Max. :43.0 Max. :224.00 Max. :96651   
## Family CCAvg Education Mortgage   
## Min. :1.000 Min. : 0.000 Min. :1.000 Min. : 0.0   
## 1st Qu.:1.000 1st Qu.: 0.700 1st Qu.:1.000 1st Qu.: 0.0   
## Median :2.000 Median : 1.500 Median :2.000 Median : 0.0   
## Mean :2.396 Mean : 1.938 Mean :1.881 Mean : 56.5   
## 3rd Qu.:3.000 3rd Qu.: 2.500 3rd Qu.:3.000 3rd Qu.:101.0   
## Max. :4.000 Max. :10.000 Max. :3.000 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

#view structure of r data  
str(bank.df)

## 'data.frame': 5000 obs. of 14 variables:  
## $ ID : int 1 2 3 4 5 6 7 8 9 10 ...  
## $ Age : int 25 45 39 35 35 37 53 50 35 34 ...  
## $ Experience : int 1 19 15 9 8 13 27 24 10 9 ...  
## $ Income : int 49 34 11 100 45 29 72 22 81 180 ...  
## $ ZIP.Code : int 91107 90089 94720 94112 91330 92121 91711 93943 90089 93023 ...  
## $ Family : int 4 3 1 1 4 4 2 1 3 1 ...  
## $ CCAvg : num 1.6 1.5 1 2.7 1 0.4 1.5 0.3 0.6 8.9 ...  
## $ Education : int 1 1 1 2 2 2 2 3 2 3 ...  
## $ Mortgage : int 0 0 0 0 0 155 0 0 104 0 ...  
## $ Personal.Loan : int 0 0 0 0 0 0 0 0 0 1 ...  
## $ Securities.Account: int 1 1 0 0 0 0 0 0 0 0 ...  
## $ CD.Account : int 0 0 0 0 0 0 0 0 0 0 ...  
## $ Online : int 0 0 0 0 0 1 1 0 1 0 ...  
## $ CreditCard : int 0 0 0 0 1 0 0 1 0 0 ...

#print a list of variables to the screen  
names(bank.df)

## [1] "ID" "Age" "Experience"   
## [4] "Income" "ZIP.Code" "Family"   
## [7] "CCAvg" "Education" "Mortgage"   
## [10] "Personal.Loan" "Securities.Account" "CD.Account"   
## [13] "Online" "CreditCard"

t(t(names(bank.df)))

## [,1]   
## [1,] "ID"   
## [2,] "Age"   
## [3,] "Experience"   
## [4,] "Income"   
## [5,] "ZIP.Code"   
## [6,] "Family"   
## [7,] "CCAvg"   
## [8,] "Education"   
## [9,] "Mortgage"   
## [10,] "Personal.Loan"   
## [11,] "Securities.Account"  
## [12,] "CD.Account"   
## [13,] "Online"   
## [14,] "CreditCard"

## REMOVE COLUMNS ID & ZIP CODE FROM DATASET  
#eliminate variables ID & Zip Code from dataset   
df=subset(bank.df, select=-c(ID, ZIP.Code))  
  
## TRANSFORM CATEGORICAL PREDICTOR WITH MORE THAN 2 CATEGORIES INTO A DUMMY VARIABLE  
  
dumedu <- as.data.frame(dummy.code(bank.df$Education))  
  
df\_without\_education <- subset(df, select=-c(Education)) #eliminating education variable  
bank\_data <- cbind(df\_without\_education, dumedu) # combined main dataset  
head(bank\_data)

## Age Experience Income Family CCAvg Mortgage Personal.Loan Securities.Account  
## 1 25 1 49 4 1.6 0 0 1  
## 2 45 19 34 3 1.5 0 0 1  
## 3 39 15 11 1 1.0 0 0 0  
## 4 35 9 100 1 2.7 0 0 0  
## 5 35 8 45 4 1.0 0 0 0  
## 6 37 13 29 4 0.4 155 0 0  
## CD.Account Online CreditCard 1 3 2  
## 1 0 0 0 1 0 0  
## 2 0 0 0 1 0 0  
## 3 0 0 0 1 0 0  
## 4 0 0 0 0 0 1  
## 5 0 0 1 0 0 1  
## 6 0 1 0 0 0 1

bank\_data$Personal.Loan = as.factor(bank\_data$Personal.Loan)  
bank\_data$CCAvg = as.integer(bank\_data$CCAvg)  
  
#Partitioning the data into Training(60%) and Validation(40%)  
#library(caret)  
set.seed(1) #set seed for reproducting the partition  
  
#randomly sample 60% of the row IDs for training; the remaining 40% serve as  
#validation, you can use any number in the parenthesis you like  
train\_rows <- sample(rownames(bank\_data), dim(bank.df)[1]\*0.6)  
train\_data = bank\_data[train\_rows,] #3001 observations  
valid\_rows <- setdiff(rownames(bank\_data), train\_rows)  
valid\_data <- bank\_data[valid\_rows, ]  
  
#new customer  
new.df <- data.frame(Age = as.integer(40), Experience = as.integer(10),  
 Income = as.integer(84), Family = as.integer(2), CCAvg = as.integer(2),  
 Education1 = as.integer(0), Education2 = as.integer(1), Education3 = as.integer(0),  
 Mortgage = as.integer(0), Securities.Account = as.integer(0), CD.Account = as.integer(0),  
 Online = as.integer(1), Credit.Card = as.integer(1))  
new.df

## Age Experience Income Family CCAvg Education1 Education2 Education3 Mortgage  
## 1 40 10 84 2 2 0 1 0 0  
## Securities.Account CD.Account Online Credit.Card  
## 1 0 0 1 1

#initialize normalized training, validation data, complete data frames to originals  
train.norm.df <- train\_data  
valid.norm.df <- valid\_data  
bank.norm.df <- bank\_data  
maindata.norm.df <- bank\_data  
  
#use PreProcess() from the caret package to normalize columns  
norm.values <- preProcess(train\_data[, -7], method=c("center", "scale"))  
train.norm.df[, -7] <-predict(norm.values, train\_data[, -7])  
valid.norm.df[, -7] <-predict(norm.values, valid\_data[, -7])  
bank.norm.df[, -7] <-predict(norm.values, bank\_data[, -7])  
  
#use knn() to compute knn  
knn.1 <- knn(train = train.norm.df[, -7], test = bank.norm.df[, -7], cl = train.norm.df[, 7], k=5, prob=TRUE)  
knn.attributes <- attributes(knn.1)  
knn.attributes[1]

## $levels  
## [1] "0" "1"

knn.attributes[3]

## $prob  
## [1] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.8 1.0 1.0 1.0 0.8 1.0  
## [19] 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [37] 1.0 1.0 0.8 1.0 0.8 1.0 0.6 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0  
## [55] 1.0 1.0 0.6 0.8 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [73] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0  
## [91] 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [109] 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [127] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [145] 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0  
## [163] 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [181] 1.0 1.0 1.0 0.8 1.0 0.8 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [199] 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [217] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [235] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [253] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0  
## [271] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [289] 0.8 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.6 1.0 1.0  
## [307] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.8 0.8  
## [325] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 0.8 1.0 1.0 1.0  
## [343] 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [361] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0  
## [379] 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [397] 1.0 1.0 1.0 1.0 0.8 1.0 0.8 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [415] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [433] 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [451] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 0.8 0.8 1.0 1.0 1.0  
## [469] 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [487] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [505] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [523] 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.6 1.0 1.0  
## [541] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [559] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0  
## [577] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 0.8 1.0 1.0 1.0 0.8 1.0  
## [595] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0  
## [613] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6  
## [631] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [649] 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0  
## [667] 0.8 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [685] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [703] 0.6 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [721] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.6  
## [739] 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0  
## [757] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0  
## [775] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.8 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [793] 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.6  
## [811] 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [829] 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [847] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.8 1.0 1.0 1.0 1.0  
## [865] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [883] 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.8 1.0 1.0 0.8  
## [901] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0  
## [919] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0  
## [937] 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.8 0.8 0.8 1.0  
## [955] 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [973] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [991] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.6  
## [1009] 1.0 1.0 0.8 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 0.6 1.0  
## [1027] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [1045] 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1063] 0.8 1.0 1.0 0.8 0.8 1.0 0.6 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 0.6 1.0 1.0  
## [1081] 1.0 1.0 0.8 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [1099] 1.0 1.0 1.0 1.0 0.8 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1117] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.8 1.0 0.6 1.0 1.0  
## [1135] 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.6 1.0 0.6 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8  
## [1153] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.8 1.0 0.6 0.8 1.0 1.0  
## [1171] 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.6 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1189] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.6 1.0  
## [1207] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1225] 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [1243] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1261] 1.0 1.0 1.0 0.6 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.6 1.0 0.8  
## [1279] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0  
## [1297] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1315] 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0  
## [1333] 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1351] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1369] 1.0 1.0 1.0 1.0 0.8 0.8 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1387] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1405] 1.0 1.0 1.0 0.6 0.8 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 0.6 1.0 1.0 1.0  
## [1423] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1441] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1459] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [1477] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1495] 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0  
## [1513] 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.8 1.0 1.0 1.0 1.0 1.0  
## [1531] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [1549] 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8  
## [1567] 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 0.8 1.0 0.8 1.0 0.6 1.0 1.0 0.8 0.8  
## [1585] 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1603] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0  
## [1621] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.6 1.0 1.0 1.0 1.0 1.0  
## [1639] 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1657] 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0  
## [1675] 0.6 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1693] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1711] 1.0 1.0 1.0 1.0 0.8 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0  
## [1729] 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.6 1.0 1.0 1.0 1.0 1.0  
## [1747] 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1765] 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1783] 1.0 1.0 0.8 0.8 1.0 1.0 1.0 0.8 1.0 1.0 0.8 1.0 0.8 1.0 1.0 1.0 0.6 1.0  
## [1801] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1819] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0  
## [1837] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1855] 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.6 0.8  
## [1873] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 0.8 1.0 0.6 1.0 0.8  
## [1891] 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1909] 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1927] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [1945] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [1963] 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1981] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [1999] 0.8 1.0 1.0 0.8 0.6 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2017] 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 0.8 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [2035] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.8 0.6 1.0 1.0 1.0 1.0  
## [2053] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2071] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2089] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2107] 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2125] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0  
## [2143] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.8  
## [2161] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2179] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0  
## [2197] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2215] 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0  
## [2233] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0  
## [2251] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [2269] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.8 0.8 1.0 1.0 1.0 0.8 1.0 0.6  
## [2287] 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2305] 0.8 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 0.6 1.0 0.8 1.0 1.0  
## [2323] 1.0 0.8 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0  
## [2341] 1.0 1.0 0.8 1.0 1.0 0.6 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2359] 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [2377] 1.0 1.0 0.8 1.0 1.0 1.0 0.8 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2395] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [2413] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0  
## [2431] 0.8 1.0 1.0 0.6 0.8 0.8 1.0 0.6 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [2449] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2467] 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [2485] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0  
## [2503] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2521] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.6 1.0 1.0 0.8 1.0  
## [2539] 1.0 0.6 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [2557] 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0  
## [2575] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 0.6 1.0 1.0 1.0 1.0 1.0  
## [2593] 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2611] 1.0 1.0 1.0 0.8 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.8 1.0 1.0  
## [2629] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2647] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [2665] 0.8 0.6 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [2683] 1.0 1.0 0.8 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2701] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0  
## [2719] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2737] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.8 1.0 1.0 1.0 1.0  
## [2755] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.8 1.0 1.0 1.0 1.0 0.8 1.0 1.0  
## [2773] 0.6 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2791] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0  
## [2809] 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0  
## [2827] 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2845] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.8 1.0 0.6 1.0 1.0  
## [2863] 1.0 1.0 1.0 1.0 0.8 0.8 1.0 1.0 1.0 0.8 1.0 1.0 0.6 1.0 1.0 1.0 0.8 1.0  
## [2881] 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2899] 0.8 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 0.6 1.0 0.8 1.0 1.0 1.0  
## [2917] 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2935] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 0.8 1.0 1.0 1.0 0.6  
## [2953] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0  
## [2971] 0.8 1.0 0.8 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [2989] 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 0.8 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0  
## [3007] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3025] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 0.8 1.0 0.6 1.0 1.0  
## [3043] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.8 1.0 1.0 1.0  
## [3061] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3079] 1.0 1.0 1.0 0.8 1.0 0.6 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3097] 0.6 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0  
## [3115] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3133] 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.6 1.0 0.6 0.8 1.0 1.0 1.0 1.0  
## [3151] 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [3169] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3187] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3205] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [3223] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3241] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [3259] 1.0 1.0 0.8 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.6 1.0 0.8 0.8 1.0 1.0 1.0 0.8  
## [3277] 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.6 1.0 0.6 1.0 1.0 1.0  
## [3295] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3313] 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.6 1.0 1.0  
## [3331] 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3349] 1.0 0.8 0.8 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3367] 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.6  
## [3385] 1.0 1.0 0.6 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3403] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3421] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3439] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3457] 0.8 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.6 1.0  
## [3475] 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3493] 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.6 0.6 1.0  
## [3511] 1.0 1.0 0.6 1.0 1.0 0.8 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3529] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.8 1.0 1.0 1.0  
## [3547] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.6  
## [3565] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 0.6 1.0 1.0 1.0 1.0 0.6 0.8 1.0 1.0  
## [3583] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3601] 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0  
## [3619] 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3637] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0  
## [3655] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3673] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3691] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0  
## [3709] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0  
## [3727] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0  
## [3745] 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [3763] 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0  
## [3781] 1.0 0.6 1.0 1.0 0.6 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3799] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3817] 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [3835] 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [3853] 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0  
## [3871] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.6 1.0 0.8 1.0  
## [3889] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3907] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.8 1.0 1.0 1.0  
## [3925] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [3943] 1.0 0.8 1.0 0.6 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6  
## [3961] 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [3979] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.6 1.0 1.0 1.0  
## [3997] 1.0 1.0 1.0 0.8 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4015] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 0.6 0.6 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0  
## [4033] 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [4051] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4069] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0  
## [4087] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4105] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4123] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 0.8 0.8  
## [4141] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0  
## [4159] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 0.6 1.0 0.6 1.0 1.0 1.0 1.0 1.0 0.6  
## [4177] 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0  
## [4195] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4213] 1.0 1.0 0.8 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4231] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4249] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [4267] 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0  
## [4285] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [4303] 1.0 1.0 1.0 0.8 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4321] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [4339] 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 0.6 1.0  
## [4357] 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4375] 0.8 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4393] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [4411] 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0  
## [4429] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 0.8 1.0 1.0 1.0  
## [4447] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4465] 1.0 1.0 0.8 0.8 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0  
## [4483] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4501] 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4519] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0  
## [4537] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4555] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 0.8 0.8  
## [4573] 1.0 0.8 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [4591] 0.6 1.0 1.0 0.6 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4609] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 0.8  
## [4627] 1.0 0.6 0.8 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4645] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0  
## [4663] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 0.8 1.0 1.0 1.0 0.6 1.0  
## [4681] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [4699] 0.6 1.0 1.0 1.0 0.6 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4717] 1.0 1.0 1.0 0.8 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8  
## [4735] 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4753] 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4771] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4789] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4807] 1.0 1.0 1.0 1.0 1.0 0.6 0.8 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.6 1.0 1.0 0.6  
## [4825] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4843] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6  
## [4861] 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0  
## [4879] 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 0.8 1.0 1.0  
## [4897] 1.0 1.0 1.0 0.8 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6  
## [4915] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 1.0 1.0 1.0  
## [4933] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8 0.6 1.0 1.0 1.0 1.0 1.0 1.0 1.0  
## [4951] 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 1.0 0.8 0.8 0.8 1.0 1.0 1.0  
## [4969] 1.0 1.0 1.0 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.6 0.8 1.0 1.0 1.0 1.0  
## [4987] 0.8 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0

row.names(train\_data)[attr(knn.1, "knn.1.index")]

## character(0)

##Measure accuracy of different k values  
#initialize a data frame with two columns: k and accuracy  
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[, -7], valid.norm.df[, -7], cl = train.norm.df[, 7], k = i)  
 accuracy.df[i, 2] <- confusionMatrix(knn.pred, as.factor(valid.norm.df[,7]))$overall[1]  
}  
accuracy.df

## k accuracy  
## 1 1 0.9625  
## 2 2 0.9560  
## 3 3 0.9640  
## 4 4 0.9535  
## 5 5 0.9590  
## 6 6 0.9535  
## 7 7 0.9580  
## 8 8 0.9510  
## 9 9 0.9545  
## 10 10 0.9490  
## 11 11 0.9515  
## 12 12 0.9490  
## 13 13 0.9500  
## 14 14 0.9455

##Since maximum accuracy is 0.9640 on line 3, the best k is 3  
#Question 2: The value of k that balances between overfitting and ignoring the predictor information is k = 3  
#since k = 3 provides the maximum accuracy in k-NN above  
  
#Question 3: The confusion matrix for the validation data that results from using the best k is below, k=3:  
##show the confusion matrix for the validation data that results from using the best k  
knn.pred.new <- knn(train = train.norm.df[, -7], test = valid.norm.df[, -7], cl = train.norm.df[, 7], k=3, prob=TRUE)  
confusionMatrix(knn.pred.new, as.factor(valid.norm.df[, 7]))

## Confusion Matrix and Statistics  
##   
## Reference  
## Prediction 0 1  
## 0 1787 64  
## 1 8 141  
##   
## Accuracy : 0.964   
## 95% CI : (0.9549, 0.9717)  
## No Information Rate : 0.8975   
## P-Value [Acc > NIR] : < 2.2e-16   
##   
## Kappa : 0.7774   
##   
## Mcnemar's Test P-Value : 9.063e-11   
##   
## Sensitivity : 0.9955   
## Specificity : 0.6878   
## Pos Pred Value : 0.9654   
## Neg Pred Value : 0.9463   
## Prevalence : 0.8975   
## Detection Rate : 0.8935   
## Detection Prevalence : 0.9255   
## Balanced Accuracy : 0.8417   
##   
## 'Positive' Class : 0   
##

#Question 4: Consider followng customer and classify using the best k  
newcust = data.frame(Age = 40, Experience = 10, Income = 84, Family = 2, CCAvg = 2, Education\_1 = 0, Education\_2 = 1, Education\_3 = 0, Mortgage = 0, Securities.Account = 0, CD.Account = 0, Online = 1, CreditCard = 1)  
knn2 <- knn(train = train.norm.df[, -7], test = newcust, cl = train.norm.df[,7], k=3, prob=TRUE)  
knn2

## [1] 1  
## attr(,"prob")  
## [1] 1  
## attr(,"nn.index")  
## [,1] [,2] [,3]  
## [1,] 2721 2146 939  
## attr(,"nn.dist")  
## [,1] [,2] [,3]  
## [1,] 90.49787 90.52875 90.53078  
## Levels: 1

#Classify customer using the best k (perform k-NN classification on test data)  
#repartition the data into training, validation and test set (50%, 30%, 20%) and apply k-NN method with k chosen above  
#set seed  
set.seed(1)  
  
prediction <-knn(train = train.norm.df[, -7], test = valid.norm.df[, -7], cl = train.norm.df[, 7], k = 3, prob=TRUE)  
actual = valid.norm.df$Personal.Loan  
prediction\_prob = attr(prediction, "prob")  
  
##ANSWER 3: The best k value is k=3  
table(prediction,actual)

## actual  
## prediction 0 1  
## 0 1787 64  
## 1 8 141

prediction\_test <- knn(train = maindata.norm.df[, -7], test = newcust, cl = maindata.norm.df[, 7], k=1, prob=TRUE)  
head(prediction\_test)

## [1] 0  
## Levels: 0

##ANSWER 4: k-NN model predicts that new customer will accept loan offer  
  
#Question 5: Repartition the data, this time into training, validation and test sets (50%, 30%, 20%)  
#Apply k-NN method with the k chosen above  
#Compare confusion matrix of the test set with that of the training and validation sets  
#Comment on the differences and their reason  
  
library(dplyr)

## Warning: package 'dplyr' was built under R version 4.1.3

##   
## 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

set.seed(1)  
  
#randomly sample 50% of the row IDs for training  
train.rows <- sample(rownames(bank\_data), dim(bank\_data)[1]\*0.5)  
  
#sample 30% of the row IDs into the validation set, drawing only from records not already in training set  
#use setdiff() to find records not already in the training set  
valid.rows <- sample(setdiff(rownames(bank\_data), train.rows), dim(bank\_data)[1]\*0.3)  
  
#assign remaining 20% row IDs to serve as test  
test.rows = setdiff(rownames(bank\_data), union(train.rows, valid.rows))  
  
#create the 3 data frames by collecting all columns from appropriate rows  
train.data <- bank\_data[train.rows, ]  
valid.data <- bank\_data[valid.rows, ]  
test.data <- bank\_data[test.rows, ]  
  
#normalize datasets  
#use PreProcess() from the caret package to normalize columns  
norm.values <- preProcess(train.data[, -7], method=c("center", "scale"))  
train.data[, -7] <-predict(norm.values, train.data[, -7])  
valid.data[, -7] <-predict(norm.values, valid.data[, -7])  
test.data[, -7] <-predict(norm.values, test.data[, -7])  
head(test.data)

## Age Experience Income Family CCAvg Mortgage  
## 2 -0.03247652 -0.09897283 -0.8495424 0.5214968 -0.2819382 -0.5696473  
## 8 0.40878053 0.34114115 -1.1117495 -1.2168258 -0.8517407 -0.5696473  
## 13 0.23227771 0.25311836 0.8985052 -0.3476645 0.8576666 -0.5696473  
## 18 -0.29723075 -0.18699563 0.1774356 1.3906581 0.2878642 -0.5696473  
## 19 0.05577489 0.07707276 2.6247021 -0.3476645 3.7066787 -0.5696473  
## 20 0.85003759 0.69323234 -1.1336001 -1.2168258 -0.8517407 -0.5696473  
## Personal.Loan Securities.Account CD.Account Online CreditCard 1  
## 2 0 2.979576 -0.2462642 -1.203329 -0.6426994 1.1787711  
## 8 0 -0.335484 -0.2462642 -1.203329 1.5553150 -0.8480018  
## 13 0 2.979576 -0.2462642 -1.203329 -0.6426994 -0.8480018  
## 18 0 -0.335484 -0.2462642 -1.203329 -0.6426994 1.1787711  
## 19 1 -0.335484 -0.2462642 -1.203329 -0.6426994 -0.8480018  
## 20 0 2.979576 -0.2462642 -1.203329 1.5553150 -0.8480018  
## 3 2  
## 2 -0.6538994 -0.6265785  
## 8 1.5286754 -0.6265785  
## 13 1.5286754 -0.6265785  
## 18 -0.6538994 -0.6265785  
## 19 1.5286754 -0.6265785  
## 20 -0.6538994 1.5953310

test.data1 <- knn(train = train.data[, -7], test = test.data[, -7], cl = train.data[, 7], k=3, prob=TRUE)  
valid.data1 <- knn(train = train.data[, -7], test = valid.data[, -7], cl = train.data[, 7], k=3, prob=TRUE)  
train.data1 <- knn(train = train.data[, -7], test = train.data[, -7], cl = train.data[, 7], k=3, prob=TRUE)  
  
confusionMatrix(test.data1, test.data[, 7])

## Confusion Matrix and Statistics  
##   
## Reference  
## Prediction 0 1  
## 0 885 35  
## 1 3 77  
##   
## Accuracy : 0.962   
## 95% CI : (0.9482, 0.973)  
## No Information Rate : 0.888   
## P-Value [Acc > NIR] : < 2.2e-16   
##   
## Kappa : 0.7817   
##   
## Mcnemar's Test P-Value : 4.934e-07   
##   
## Sensitivity : 0.9966   
## Specificity : 0.6875   
## Pos Pred Value : 0.9620   
## Neg Pred Value : 0.9625   
## Prevalence : 0.8880   
## Detection Rate : 0.8850   
## Detection Prevalence : 0.9200   
## Balanced Accuracy : 0.8421   
##   
## 'Positive' Class : 0   
##

confusionMatrix(valid.data1, valid.data[, 7])

## Confusion Matrix and Statistics  
##   
## Reference  
## Prediction 0 1  
## 0 1360 44  
## 1 4 92  
##   
## Accuracy : 0.968   
## 95% CI : (0.9578, 0.9763)  
## No Information Rate : 0.9093   
## P-Value [Acc > NIR] : < 2.2e-16   
##   
## Kappa : 0.7763   
##   
## Mcnemar's Test P-Value : 1.811e-08   
##   
## Sensitivity : 0.9971   
## Specificity : 0.6765   
## Pos Pred Value : 0.9687   
## Neg Pred Value : 0.9583   
## Prevalence : 0.9093   
## Detection Rate : 0.9067   
## Detection Prevalence : 0.9360   
## Balanced Accuracy : 0.8368   
##   
## 'Positive' Class : 0   
##

confusionMatrix(train.data1, train.data[, 7])

## Confusion Matrix and Statistics  
##   
## Reference  
## Prediction 0 1  
## 0 2264 51  
## 1 4 181  
##   
## Accuracy : 0.978   
## 95% CI : (0.9715, 0.9834)  
## No Information Rate : 0.9072   
## P-Value [Acc > NIR] : < 2.2e-16   
##   
## Kappa : 0.8563   
##   
## Mcnemar's Test P-Value : 5.552e-10   
##   
## Sensitivity : 0.9982   
## Specificity : 0.7802   
## Pos Pred Value : 0.9780   
## Neg Pred Value : 0.9784   
## Prevalence : 0.9072   
## Detection Rate : 0.9056   
## Detection Prevalence : 0.9260   
## Balanced Accuracy : 0.8892   
##   
## 'Positive' Class : 0   
##

#ANSWER 5:   
#Test Accuracy 0.959  
#Valid Accuracy 0.9627  
#Train Accuracy 0.9748  
#Training Dataset has the highest acccuracy, which makes sense because we drew the most data into the training set at 50%