

Coursework

Data Science Development (CMM535)

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1 Data Exploration

1.1 Dataset Choice

The dataset that has been chosen for this part of the coursework is Mushroom. This is available on the UCI repository. The set was chosen because of it's adequate instance size and number of attributes.

<http://archive.ics.uci.edu/ml/datasets/Mushroom>

1.2 Problem Statement and Data Exploration

The main purpose of the Mushroom dataset is to identify which characteristics (attributes) determine if a particular mushroom species is edible or poisonous.

Therefore the aim of this assignment is to build a predictive model to predict if a certain type of Mushroom is edible or not.

To start off the data exploration I will first import the required packages.

```
#Import packages
library(randomForest)
library(e1071)
library(caret)
library(ggplot2)
library(gridExtra)
library(caret)
library(rpart.plot)
library(RColorBrewer)
library(plyr)
library(dplyr)
library(doParallel)
library(xtable)
```

Then set the working directory to the Coursework project folder path:

```
setwd("~/CMM535 Data Science Development/Coursework/CMM535_Coursework")
```

In order to import the dataset, I used a third party helper function, which can be viewed at (Figure 4.1) . The helper function not only set the attributes names but the instances names as well. Since all the data is represented a single character, it converts them into their string equivalent.

```
#helper function
source('helper_functions.r')

#Import datasets using helper function

mushroom <- fetchAndCleanData()
```

Now that the dataset is imported, it is time to do some data exploration and analysis.
Number of rows in the dataset:

```
#Number of rows in the dataset
nrow(mushroom)
```

```
## [1] 8124
```

Number of columns (features) in the dataset:

```
ncol(mushroom)
```

```
## [1] 23
```

Summary of the Mushroom dataset:

```
#Summary of the Mushroom dataset
str(mushroom)
```

```
## 'data.frame': 8124 obs. of 23 variables:
## $ Edible : Factor w/ 2 levels "Edible","Poisonous": 2 1 1 2 1 1 1 1 2 1 ...
## $ CapShape : Factor w/ 12 levels "b","c","f","k",...: 9 9 7 9 9 9 7 7 9 7 ...
## $ CapSurface : Factor w/ 8 levels "f","g","s","y",...: 8 8 8 7 8 7 8 7 7 8 ...
## $ CapColor : Factor w/ 20 levels "b","c","e","g",...: 11 20 19 19 14 20 19 19 19 20 ...
## $ Bruises : Factor w/ 4 levels "f","t","True",...: 3 3 3 3 4 3 3 3 3 3 ...
## $ Odor : Factor w/ 18 levels "a","c","f","l",...: 17 10 11 17 16 10 10 11 17 10 ...
## $ GillAttachment : Factor w/ 6 levels "a","f","Attached",...: 5 5 5 5 5 5 5 5 5 5 ...
## $ GillSpacing : Factor w/ 5 levels "c","w","Close",...: 3 3 3 3 4 3 3 3 3 3 ...
## $ GillSize : Factor w/ 4 levels "b","n","Broad",...: 4 3 3 4 3 3 3 3 4 3 ...
## $ GillColor : Factor w/ 24 levels "b","e","g","h",...: 13 13 14 14 13 14 17 14 20 17 ...
## $ StalkShape : Factor w/ 4 levels "e","t","Enlarging",...: 3 3 3 3 4 3 3 3 3 3 ...
## $ StalkRoot : Factor w/ 12 levels "?","b","c","e",...: 9 7 7 9 9 7 7 7 9 7 ...
## $ StalkSurfaceAboveRing: Factor w/ 8 levels "f","k","s","y",...: 8 8 8 8 8 8 8 8 8 ...
## $ StalkSurfaceBelowRing: Factor w/ 8 levels "f","k","s","y",...: 8 8 8 8 8 8 8 8 8 ...
## $ StalkColorAboveRing : Factor w/ 18 levels "b","c","e","g",...: 17 17 17 17 17 17 17 17 17 17 ...
## $ StalkColorBelowRing : Factor w/ 18 levels "b","c","e","g",...: 17 17 17 17 17 17 17 17 17 17 ...
## $ VeilType : Factor w/ 3 levels "p","Partial",...: 2 2 2 2 2 2 2 2 2 2 ...
## $ VeilColor : Factor w/ 8 levels "n","o","w","y",...: 7 7 7 7 7 7 7 7 7 7 ...
## $ RingNumber : Factor w/ 6 levels "n","o","t","None",...: 5 5 5 5 5 5 5 5 5 5 ...
## $ RingType : Factor w/ 13 levels "e","f","l","n",...: 11 11 11 11 7 11 11 11 11 11 ...
## $ SporePrintColor : Factor w/ 18 levels "b","h","k","n",...: 10 11 11 10 11 10 10 11 10 10 ...
## $ Population : Factor w/ 12 levels "a","c","n","s",...: 10 9 9 10 7 9 9 10 11 10 ...
## $ Habitat : Factor w/ 14 levels "d","g","l","m",...: 12 8 10 12 8 8 10 10 8 10 ...
```

Now that some basic data exploration is covered, next to inspect the dataset a bit further. Starting with the class (Edible) distribution in the mushroom dataset, see (Figure 1)

```
#Class Distribution
barplot(table(mushroom$Edible))
```

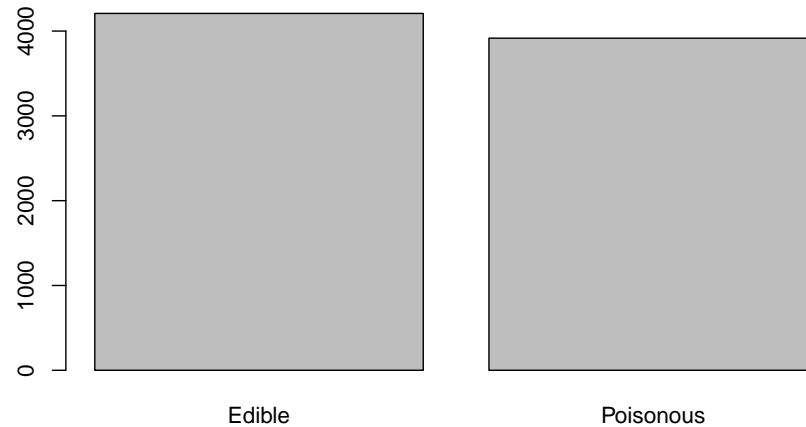


Figure 1: Barplot of Class Distribution

Next is to analyse if there is a correlation between the CapShape and CapSurface of a mushroom and whether it is Edible or Poisonous. Which is shown in the plot ((Figure 2)) below.

```
#Comparisons of CapShape and CapSurface with Edible or Poisonous
ggplot(mushroom, aes(x=CapShape, y=CapSurface, color=Edible)) +
  geom_jitter(alpha=0.3) +
  scale_color_manual(breaks = c('Edible', 'Poisonous'),
                    values=c('darkgreen', 'red'))
```

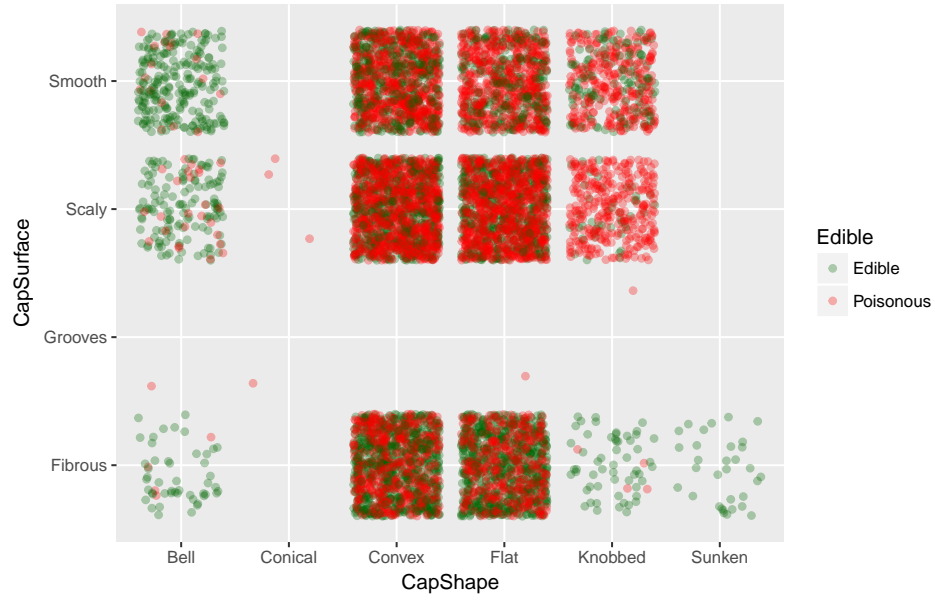


Figure 2: Comparisons of CapShape and CapSurface with Edible or Poisonous in Mushroom Dataset

```
#Comparisons of StalkSurfaceAboveRing and StalkSurfaceBelowRing with Edible or Poisonous
ggplot(mushroom, aes(x=StalkSurfaceAboveRing, y=StalkSurfaceBelowRing, color=Edible)) +
  geom_jitter(alpha=0.3) +
  scale_color_manual(breaks = c('Edible', 'Poisonous'), values=c('darkgreen', 'red'))
```

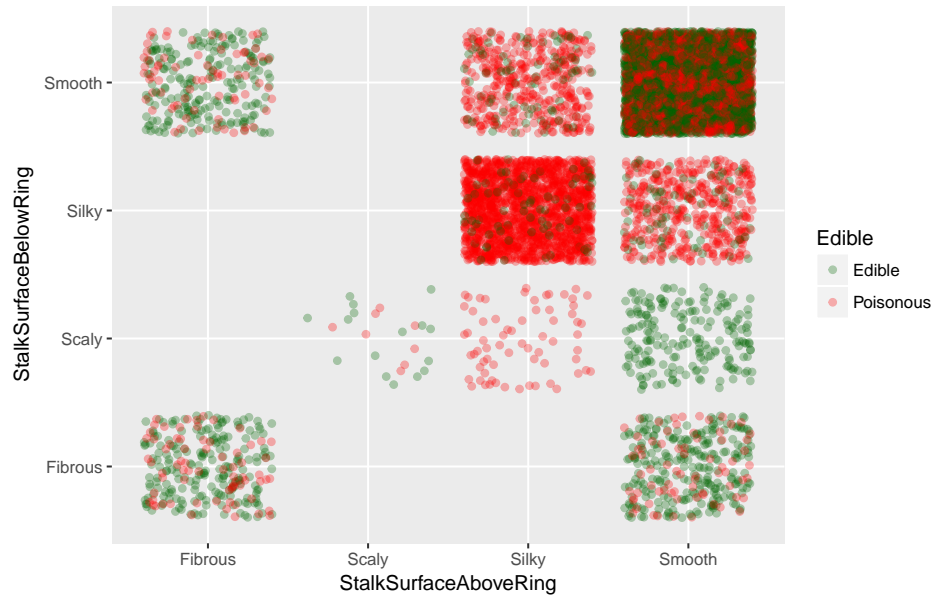


Figure 3: Comparisons of StalkSurfaceAboveRing and StalkSurfaceBelowRing with Edible or Poisonous

1.3 Pre-Processing

Before the Mushroom dataset can be processed by a classification model(s), some pre-processing is required. While the helper function should take out all missing values, let's validate this before continuing.

```
#Class Distribution  
table(complete.cases (mushroom))
```

```
##  
## TRUE  
## 8124
```

As shown above, there is not any missing values in the dataset.

2 Modeling and Classification

2.1 Divide into training and testing subset

When it came to dividing the mushroom dataset into training and testing subsets, I decided to go with the conventional 70 percent training and 30 percent testing split as a starting point/baseline.

```
#Divide the dataset into 70% training and 30% testing.
inTrain <- createDataPartition(y=mushroom$Edible, p=0.7, list=FALSE)

#Assign indexes to split the Mushroom dataset into training and testing
training <- mushroom[inTrain,]
testing <- mushroom[-inTrain,]
```

2.2 Build Classifier

For the initial classifier I decided to go with the kNN Classifier as it has proven to be a good baseline in previous labs and exercises in R.

Before the classification begins, parallel processing is enabled to speed up this process.

```
#Setup Parallel processing to speed up classification modelling
cl <- makeCluster(detectCores(), type='PSOCK')
registerDoParallel(cl)
```

The train control is set to cross-validation with 5 folds:

```
#set train control to cross-validation with 5 folds
train_control<- trainControl(method="cv", number=5)
```

```
#First set the seed for reproducibility
set.seed(1)

#train model using kNN
kNNModel <- train(Edible ~ ., data = training,
                  trControl = train_control,
                  tuneLength = 20,
                  method = "knn"
)
```

Once the knn Model is complete, it's time to analyse the results, first with a print of the kNNModel as shown below.

```
#Show the kNN model results
kNNModel
```

```
## k-Nearest Neighbors
##
## 5688 samples
## 22 predictor
## 2 classes: 'Edible', 'Poisonous'
##
## No pre-processing
```

```
## Resampling: Cross-Validated (5 fold)
## Summary of sample sizes: 4551, 4549, 4551, 4551, 4550
## Resampling results across tuning parameters:
##
##   k   Accuracy   Kappa
##   5  0.9992964  0.9985907
##   7  0.9989446  0.9978860
##   9  0.9987687  0.9975336
##  11  0.9984169  0.9968289
##  13  0.9980654  0.9961249
##  15  0.9978895  0.9957725
##  17  0.9980654  0.9961249
##  19  0.9975377  0.9950681
##  21  0.9973618  0.9947159
##  23  0.9975377  0.9950683
##  25  0.9971863  0.9943648
##  27  0.9966591  0.9933090
##  29  0.9959561  0.9919015
##  31  0.9954287  0.9908461
##  33  0.9950768  0.9901412
##  35  0.9945492  0.9890853
##  37  0.9940215  0.9880294
##  39  0.9933181  0.9866213
##  41  0.9920878  0.9841591
##  43  0.9908568  0.9816959
##
## Accuracy was used to select the optimal model using the largest value.
## The final value used for the model was k = 5.
```

Next is a confusion matrix is created by predicting the accuracy against the testing subset.

```
#Predict the accuracy of the kNN Model against the testing set
predictkNN <- predict(kNNModel,testing)
confusionMatrix(predictkNN, testing$Edible)
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction  Edible Poisonous
##   Edible      1262         0
##   Poisonous     0       1174
##
##               Accuracy : 1
##               95% CI : (0.9985, 1)
##   No Information Rate : 0.5181
##   P-Value [Acc > NIR] : < 2.2e-16
##
##               Kappa : 1
##   Mcnemar's Test P-Value : NA
##
##               Sensitivity : 1.0000
##               Specificity : 1.0000
##               Pos Pred Value : 1.0000
```

```
##      Neg Pred Value : 1.0000
##      Prevalence : 0.5181
##      Detection Rate : 0.5181
##      Detection Prevalence : 0.5181
##      Balanced Accuracy : 1.0000
##
##      'Positive' Class : Edible
##
```


2.3 Improve Model Performance

2.3.1 C5.0 Model

```
#First set the seed for reproducibility
set.seed(1)

#train the model using c5.0
c50Model<- train(Edible~., data=training,
                 trControl=train_control,
                 tuneLength=5,
                 method="C5.0"
)
```

```
#Show the c50Model results
c50Model
```

```
## C5.0
##
## 5688 samples
## 22 predictor
## 2 classes: 'Edible', 'Poisonous'
##
## No pre-processing
## Resampling: Cross-Validated (5 fold)
## Summary of sample sizes: 4551, 4549, 4551, 4551, 4550
## Resampling results across tuning parameters:
##
##  model  winnow  trials  Accuracy  Kappa
##  rules  FALSE   1      1.0000000  1.0000000
##  rules  FALSE  10      1.0000000  1.0000000
##  rules  FALSE  20      1.0000000  1.0000000
##  rules  FALSE  30      1.0000000  1.0000000
##  rules  FALSE  40      1.0000000  1.0000000
##  rules  FALSE  50      1.0000000  1.0000000
##  rules  FALSE  60      1.0000000  1.0000000
##  rules  FALSE  70      1.0000000  1.0000000
##  rules  FALSE  80      1.0000000  1.0000000
##  rules  FALSE  90      1.0000000  1.0000000
##  rules  TRUE    1      0.9991216  0.9982406
##  rules  TRUE   10      1.0000000  1.0000000
##  rules  TRUE   20      1.0000000  1.0000000
##  rules  TRUE   30      1.0000000  1.0000000
##  rules  TRUE   40      0.9996485  0.9992961
##  rules  TRUE   50      0.9996485  0.9992961
##  rules  TRUE   60      0.9996485  0.9992961
##  rules  TRUE   70      0.9996485  0.9992961
##  rules  TRUE   80      0.9996485  0.9992961
##  rules  TRUE   90      0.9996485  0.9992961
##  tree   FALSE   1      1.0000000  1.0000000
##  tree   FALSE  10      1.0000000  1.0000000
##  tree   FALSE  20      1.0000000  1.0000000
```

```
## tree FALSE 30 1.0000000 1.0000000
## tree FALSE 40 1.0000000 1.0000000
## tree FALSE 50 1.0000000 1.0000000
## tree FALSE 60 1.0000000 1.0000000
## tree FALSE 70 1.0000000 1.0000000
## tree FALSE 80 1.0000000 1.0000000
## tree FALSE 90 1.0000000 1.0000000
## tree TRUE 1 0.9994728 0.9989440
## tree TRUE 10 1.0000000 1.0000000
## tree TRUE 20 1.0000000 1.0000000
## tree TRUE 30 1.0000000 1.0000000
## tree TRUE 40 1.0000000 1.0000000
## tree TRUE 50 1.0000000 1.0000000
## tree TRUE 60 1.0000000 1.0000000
## tree TRUE 70 1.0000000 1.0000000
## tree TRUE 80 1.0000000 1.0000000
## tree TRUE 90 1.0000000 1.0000000
##
## Accuracy was used to select the optimal model using the largest value.
## The final values used for the model were trials = 1, model = rules
## and winnow = FALSE.
```

```
predictC50 <- predict(c50Model, testing)
confusionMatrix(predictC50,testing$Edible)
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction  Edible Poisonous
## Edible      1262         0
## Poisonous    0         1174
##
##           Accuracy : 1
##           95% CI : (0.9985, 1)
## No Information Rate : 0.5181
## P-Value [Acc > NIR] : < 2.2e-16
##
##           Kappa : 1
## Mcnemar's Test P-Value : NA
##
##           Sensitivity : 1.0000
##           Specificity : 1.0000
##           Pos Pred Value : 1.0000
##           Neg Pred Value : 1.0000
##           Prevalence : 0.5181
##           Detection Rate : 0.5181
## Detection Prevalence : 0.5181
##           Balanced Accuracy : 1.0000
##
##           'Positive' Class : Edible
##
```

2.3.2 Random forest Model

```
#First set the seed for reproducibility
set.seed(1)

# train the model using random forest
RFModel<- train(Edible~., data=training,
               trControl=train_control,
               method="rf",
               tuneLength =10,
               metric = 'Accuracy'
)
```

RFModel

```
## Random Forest
##
## 5688 samples
## 22 predictor
## 2 classes: 'Edible', 'Poisonous'
##
## No pre-processing
## Resampling: Cross-Validated (5 fold)
## Summary of sample sizes: 4551, 4549, 4551, 4551, 4550
## Resampling results across tuning parameters:
##
## mtry Accuracy Kappa
## 2 0.8957470 0.7896431
## 26 1.0000000 1.0000000
## 50 1.0000000 1.0000000
## 75 1.0000000 1.0000000
## 99 1.0000000 1.0000000
## 123 0.9998241 0.9996477
## 148 0.9998241 0.9996477
## 172 0.9996484 0.9992958
## 196 0.9996484 0.9992958
## 221 0.9996484 0.9992958
##
## Accuracy was used to select the optimal model using the largest value.
## The final value used for the model was mtry = 26.
```

```
predictRF <- predict(RFModel,testing)
confusionMatrix(predictRF, testing$Edible)
```

```
## Confusion Matrix and Statistics
##
##              Reference
## Prediction  Edible Poisonous
## Edible      1262      0
## Poisonous    0      1174
```

```
##
##           Accuracy : 1
##           95% CI : (0.9985, 1)
##       No Information Rate : 0.5181
##       P-Value [Acc > NIR] : < 2.2e-16
##
##           Kappa : 1
##  McNemar's Test P-Value : NA
##
##       Sensitivity : 1.0000
##       Specificity : 1.0000
##       Pos Pred Value : 1.0000
##       Neg Pred Value : 1.0000
##       Prevalence : 0.5181
##       Detection Rate : 0.5181
##       Detection Prevalence : 0.5181
##       Balanced Accuracy : 1.0000
##
##       'Positive' Class : Edible
##
```

2.3.3 Comparison of all Models

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction  Edible Poisonous
##   Edible      1262         0
##   Poisonous     0      1174
##
##           Accuracy : 1
##           95% CI : (0.9985, 1)
##   No Information Rate : 0.5181
##   P-Value [Acc > NIR] : < 2.2e-16
##
##           Kappa : 1
##   Mcnemar's Test P-Value : NA
##
##           Sensitivity : 1.0000
##           Specificity : 1.0000
##   Pos Pred Value : 1.0000
##   Neg Pred Value : 1.0000
##           Prevalence : 0.5181
##   Detection Rate : 0.5181
##   Detection Prevalence : 0.5181
##   Balanced Accuracy : 1.0000
##
##   'Positive' Class : Edible
##
```

3 Fine-grained Model

3.1 Clustering Dataset

3.1.1 Pre-processing

```
normalizeData <- function (x) {  
  return ( (x-min(x)) / ( max(x)- min(x) ) )  
}
```

```
#Copy the dataset before pre-processing  
dfNew <- mushroom  
dfNew$VeilType <- NULL  
  
#Convert the dataframe to numeric values  
dfNew[,2:22] = lapply(dfNew[,2:22], as.numeric)  
  
##Then use the normalise function from above  
dfN <- as.data.frame(lapply(dfNew[, -1], normalizeData))
```

3.1.2 Clustering using clustData function

```
str(dfN)  
dfN$Edible <- dfNew$Edible  
  
table(complete.cases (dfN))
```

```
## 'data.frame': 8124 obs. of 21 variables:  
## $ CapShape : num 0.4 0.4 0 0.4 0.4 0.4 0 0 0.4 0 ...  
## $ CapSurface : num 1 1 1 0.667 1 ...  
## $ CapColor : num 0 1 0.889 0.889 0.333 ...  
## $ Bruises : num 0 0 0 0 1 0 0 0 0 0 ...  
## $ Odor : num 0.875 0 0.125 0.875 0.75 0 0 0.125 0.875 0 ...  
## $ GillAttachment : num 1 1 1 1 1 1 1 1 1 1 ...  
## $ GillSpacing : num 0 0 0 0 1 0 0 0 0 0 ...  
## $ GillSize : num 1 0 0 1 0 0 0 0 1 0 ...  
## $ GillColor : num 0 0 0.0909 0.0909 0 ...  
## $ StalkShape : num 0 0 0 0 1 0 0 0 0 0 ...  
## $ StalkRoot : num 0.5 0.167 0.167 0.5 0.5 ...  
## $ StalkSurfaceAboveRing: num 1 1 1 1 1 1 1 1 1 1 ...  
## $ StalkSurfaceBelowRing: num 1 1 1 1 1 1 1 1 1 1 ...  
## $ StalkColorAboveRing : num 0.875 0.875 0.875 0.875 0.875 0.875 0.875 0.875 0.875 0.875 ...  
## $ StalkColorBelowRing : num 0.875 0.875 0.875 0.875 0.875 0.875 0.875 0.875 0.875 0.875 ...  
## $ VeilColor : num 0.667 0.667 0.667 0.667 0.667 ...  
## $ RingNumber : num 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 ...  
## $ RingType : num 1 1 1 1 0 1 1 1 1 1 ...  
## $ SporePrintColor : num 0 0.125 0.125 0 0.125 0 0 0.125 0 0 ...  
## $ Population : num 0.6 0.4 0.4 0.6 0 0.4 0.4 0.6 0.8 0.6 ...  
## $ Habitat : num 0.667 0 0.333 0.667 0 ...  
##  
## TRUE  
## 8124
```

```
clusteredDF <- clustData(dfN,ncol(dfNew), c(2,2))
head(clusteredDF,10)
```

##	CapShape	CapSurface	CapColor	Bruises	Odor	GillAttachment	GillSpacing
## 1	0.4	1.0000000	1.0000000	0	0.000	1	0
## 2	0.0	1.0000000	0.8888889	0	0.125	1	0
## 3	0.4	1.0000000	0.3333333	1	0.750	1	1
## 4	0.4	0.6666667	1.0000000	0	0.000	1	0
## 5	0.0	1.0000000	0.8888889	0	0.000	1	0
## 6	0.0	0.6666667	0.8888889	0	0.125	1	0
## 7	0.0	1.0000000	1.0000000	0	0.000	1	0
## 8	0.4	0.6666667	1.0000000	0	0.125	1	0
## 9	0.4	0.6666667	1.0000000	0	0.000	1	0
## 10	0.0	1.0000000	1.0000000	0	0.000	1	0
##	GillSize	GillColor	StalkShape	StalkRoot	StalkSurfaceAboveRing		
## 1	0	0.0000000	0	0.1666667		1	
## 2	0	0.09090909	0	0.1666667		1	
## 3	0	0.0000000	1	0.5000000		1	
## 4	0	0.09090909	0	0.1666667		1	
## 5	0	0.36363636	0	0.1666667		1	
## 6	0	0.09090909	0	0.1666667		1	
## 7	0	0.36363636	0	0.1666667		1	
## 8	0	0.36363636	0	0.1666667		1	
## 9	0	0.09090909	0	0.1666667		1	
## 10	0	0.90909091	0	0.1666667		1	
##	StalkSurfaceBelowRing	StalkColorAboveRing	StalkColorBelowRing	VeilColor			
## 1		1	0.875	0.875	0.6666667		
## 2		1	0.875	0.875	0.6666667		
## 3		1	0.875	0.875	0.6666667		
## 4		1	0.875	0.875	0.6666667		
## 5		1	0.875	0.875	0.6666667		
## 6		1	0.875	0.875	0.6666667		
## 7		1	0.875	0.875	0.6666667		
## 8		1	0.875	0.875	0.6666667		
## 9		1	0.875	0.875	0.6666667		
## 10		1	0.875	0.875	0.6666667		
##	RingNumber	RingType	SporePrintColor	Population	Habitat	cluster	
## 1	0.5	1	0.125	0.4	0.0000000	Edible_c2	
## 2	0.5	1	0.125	0.4	0.3333333	Edible_c2	
## 3	0.5	0	0.125	0.0	0.0000000	Edible_c2	
## 4	0.5	1	0.000	0.4	0.0000000	Edible_c2	
## 5	0.5	1	0.000	0.4	0.3333333	Edible_c2	
## 6	0.5	1	0.125	0.6	0.3333333	Edible_c2	
## 7	0.5	1	0.000	0.6	0.3333333	Edible_c2	
## 8	0.5	1	0.125	0.4	0.0000000	Edible_c2	
## 9	0.5	1	0.000	0.6	0.3333333	Edible_c2	
## 10	0.5	1	0.125	0.6	0.0000000	Edible_c2	

3.2 Adapting your Model

3.2.1 Refitting Random Forest to Clustering

```
#Adapting the model

#Divide the dataset into 60% training and 40% testing.
inTrainCluster <- createDataPartition(y=clusteredDF$cluster, p=0.6, list=FALSE)

#Assign indexes to split the Mushroom dataset into training and testing
trainingCluster <- clusteredDF[inTrainCluster,]
testingCluster <- clusteredDF[-inTrainCluster,]

#set train control to cross-validation with 5 folds
train_controlCluster<- trainControl(method="cv", number=10,verboseIter=FALSE)
```

```
#First set the seed for reproducibility
set.seed(1)

# train the model using random forest
RFModelCluster<- train(cluster~., data=trainingCluster,
                        trControl=train_controlCluster,
                        method="rf",
                        tuneLength =10,
                        metric = 'Accuracy'
)

#Show Random forest model
RFModelCluster
```

```
## Random Forest
##
## 4876 samples
## 21 predictor
## 4 classes: 'Edible_c1', 'Edible_c2', 'Poisonous_c1', 'Poisonous_c2'
##
## No pre-processing
## Resampling: Cross-Validated (10 fold)
## Summary of sample sizes: 4388, 4388, 4387, 4389, 4389, 4388, ...
## Resampling results across tuning parameters:
##
## mtry Accuracy Kappa
## 2 0.9993852 0.9991760
## 4 0.9993852 0.9991760
## 6 0.9993852 0.9991760
## 8 0.9993852 0.9991760
## 10 0.9993852 0.9991760
## 12 0.9993852 0.9991760
## 14 0.9993852 0.9991760
## 16 0.9993852 0.9991760
## 18 0.9993852 0.9991760
```



```
## 21 0.9995902 0.9994507
##
## Accuracy was used to select the optimal model using the largest value.
## The final value used for the model was mtry = 21.
```

```
#Predict the accuracy and display using a confusion matrix
predictRFCluster <- predict(RFModelCluster,testingCluster)
confusionMatrix(predictRFCluster, testingCluster$cluster)
```

```
## Confusion Matrix and Statistics
##
##               Reference
## Prediction      Edible_c1 Edible_c2 Poisonous_c1 Poisonous_c2
## Edible_c1         732         1           0           0
## Edible_c2          0        949           0           0
## Poisonous_c1        0         0        862           0
## Poisonous_c2        0         0         0        704
##
## Overall Statistics
##
##               Accuracy : 0.9997
##               95% CI : (0.9983, 1)
##      No Information Rate : 0.2925
##      P-Value [Acc > NIR] : < 2.2e-16
##
##               Kappa : 0.9996
##  McNemar's Test P-Value : NA
##
## Statistics by Class:
##
##               Class: Edible_c1 Class: Edible_c2 Class: Poisonous_c1
## Sensitivity                1.0000                0.9989                1.0000
## Specificity                0.9996                1.0000                1.0000
## Pos Pred Value              0.9986                1.0000                1.0000
## Neg Pred Value              1.0000                0.9996                1.0000
## Prevalence                  0.2254                0.2925                0.2654
## Detection Rate              0.2254                0.2922                0.2654
## Detection Prevalence       0.2257                0.2922                0.2654
## Balanced Accuracy           0.9998                0.9995                1.0000
##
##               Class: Poisonous_c2
## Sensitivity                1.0000
## Specificity                1.0000
## Pos Pred Value              1.0000
## Neg Pred Value              1.0000
## Prevalence                  0.2167
## Detection Rate              0.2167
## Detection Prevalence       0.2167
## Balanced Accuracy           1.0000
```

3.2.2 Results

	Edible_c1	Edible_c2	Poisonous_c1	Poisonous_c2
Edible_c1	1145	0	0	0
Edible_c2	0	537	0	0
Poisonous_c1	0	0	704	0
Poisonous_c2	0	0	0	862

	Actual	Predicted	Correct
1	Edible_c2	Edible_c2	Yes
2	Edible_c1	Edible_c1	Yes
3	Edible_c1	Edible_c1	Yes
4	Edible_c2	Edible_c2	Yes
5	Edible_c2	Edible_c2	Yes
6	Edible_c1	Edible_c1	Yes
7	Edible_c1	Edible_c1	Yes
8	Edible_c1	Edible_c1	Yes
9	Edible_c1	Edible_c1	Yes
10	Edible_c1	Edible_c1	Yes

	Actual	Predicted	Correct
3239	Poisonous_c1	Poisonous_c1	Yes
3240	Poisonous_c1	Poisonous_c1	Yes
3241	Poisonous_c1	Poisonous_c1	Yes
3242	Poisonous_c1	Poisonous_c1	Yes
3243	Poisonous_c1	Poisonous_c1	Yes
3244	Poisonous_c2	Poisonous_c2	Yes
3245	Poisonous_c1	Poisonous_c1	Yes
3246	Poisonous_c1	Poisonous_c1	Yes
3247	Poisonous_c1	Poisonous_c1	Yes
3248	Poisonous_c1	Poisonous_c1	Yes

4 Appendix

4.1 Mushroom Dataset Helper Function

I used a helper function to import the dataset, it helps with assigning the correct column and row names to the dataset. It also removes any missing values from the dataset.

https://github.com/stoltzmaniac/Mushroom-Classification/blob/master/helper_functions.R

Figure 4: fetchAndCleanData Function for Mushroom dataset

```
fetchAndCleanData = function(){  
  # All of this code is from  
  # https://rstudio-pubs-static.s3.amazonaws.com/125760_358e4a6802c94fa29e2a9ab49f45df94.html  
  
  mushrooms = read.table("data/agaricus-lepiota.data", header = FALSE, sep = ",")  
  
  #create a data frame with only the required columns  
  shrooms = mushrooms  
  
  #column names are added  
  colnames(shrooms) = c("Edible",  
                        "CapShape",  
                        "CapSurface",  
                        "CapColor",  
                        "Bruises",  
                        "Odor",  
                        "GillAttachment",  
                        "GillSpacing",  
                        "GillSize",  
                        "GillColor",  
                        "StalkShape",  
                        "StalkRoot",  
                        "StalkSurfaceAboveRing",  
                        "StalkSurfaceBelowRing",  
                        "StalkColorAboveRing",  
                        "StalkColorBelowRing",  
                        "VeilType",  
                        "VeilColor",  
                        "RingNumber",  
                        "RingType",  
                        "SporePrintColor",  
                        "Population",  
                        "Habitat")  
  
  #Edible  
  shrooms$Edible = as.character(shrooms$Edible)  
  shrooms$Edible[shrooms$Edible == "e"] = "Edible"  
  shrooms$Edible[shrooms$Edible == 'p'] = "Poisonous"  
  shrooms$Edible = factor(shrooms$Edible)  
  
  # Edible  
  #levels(shrooms$Edible) = c(levels(shrooms$Edible), c("Poisonous", "Edible"))  
  #shrooms$Edible[shrooms$Edible == "p"] = "Poisonous"  
  #shrooms$Edible[shrooms$Edible == "e"] = "Edible"  
  
  #CapShape  
  levels(shrooms$`CapShape`) = c(levels(shrooms$`CapShape`), c("Bell", "Conical", "Convex", "Flat", "Knobbed", "Sunken"))  
  shrooms$`CapShape`[shrooms$`CapShape` == "b"] = "Bell"  
  shrooms$`CapShape`[shrooms$`CapShape` == "c"] = "Conical"  
  shrooms$`CapShape`[shrooms$`CapShape` == "x"] = "Convex"  
  shrooms$`CapShape`[shrooms$`CapShape` == "f"] = "Flat"  
  shrooms$`CapShape`[shrooms$`CapShape` == "k"] = "Knobbed"  
  shrooms$`CapShape`[shrooms$`CapShape` == "s"] = "Sunken"  
  
  #CapSurface  
  levels(shrooms$`CapSurface`) = c(levels(shrooms$`CapSurface`), c("Fibrous", "Grooves", "Scaly", "Smooth"))  
  shrooms$`CapSurface`[shrooms$`CapSurface` == "f"] = "Fibrous"  
  shrooms$`CapSurface`[shrooms$`CapSurface` == "g"] = "Grooves"  
  shrooms$`CapSurface`[shrooms$`CapSurface` == "y"] = "Scaly"  
  shrooms$`CapSurface`[shrooms$`CapSurface` == "s"] = "Smooth"  
  
  #CapColor  
  levels(shrooms$`CapColor`) = c(levels(shrooms$`CapColor`), c("Brown", "Buff", "Cinnamon", "Gray", "Green", "Pink", "Purple", "Red", "White", "Yellow"))  
  shrooms$`CapColor`[shrooms$`CapColor` == "n"] = "Brown"  
  shrooms$`CapColor`[shrooms$`CapColor` == "b"] = "Buff"  
  shrooms$`CapColor`[shrooms$`CapColor` == "c"] = "Cinnamon"  
  shrooms$`CapColor`[shrooms$`CapColor` == "g"] = "Gray"  
  shrooms$`CapColor`[shrooms$`CapColor` == "r"] = "Green"  
  shrooms$`CapColor`[shrooms$`CapColor` == "p"] = "Pink"  
  shrooms$`CapColor`[shrooms$`CapColor` == "u"] = "Purple"  
  shrooms$`CapColor`[shrooms$`CapColor` == "e"] = "Red"  
  shrooms$`CapColor`[shrooms$`CapColor` == "w"] = "White"  
  shrooms$`CapColor`[shrooms$`CapColor` == "y"] = "Yellow"  
  
  # Bruises  
  levels(shrooms$Bruises) = c(levels(shrooms$Bruises), c("True", "False"))  
  shrooms$Bruises[shrooms$Bruises == "t"] = "True"  
  shrooms$Bruises[shrooms$Bruises == "f"] = "False"  
  
  #Odor
```

```

levels(shrooms$Odor) = c(levels(shrooms$Odor), c("Almond", "Anise", "Creosote", "Fishy", "Foul", "Musty", "None", "Pungent", "Spicy"))
shrooms$Odor[shrooms$Odor == "a"] = "Almond"
shrooms$Odor[shrooms$Odor == "l"] = "Anise"
shrooms$Odor[shrooms$Odor == "c"] = "Creosote"
shrooms$Odor[shrooms$Odor == "y"] = "Fishy"
shrooms$Odor[shrooms$Odor == "f"] = "Foul"
shrooms$Odor[shrooms$Odor == "m"] = "Musty"
shrooms$Odor[shrooms$Odor == "n"] = "None"
shrooms$Odor[shrooms$Odor == "p"] = "Pungent"
shrooms$Odor[shrooms$Odor == "s"] = "Spicy"

# GillAttachment
levels(shrooms$GillAttachment) = c(levels(shrooms$GillAttachment), c("Attached", "Descending", "Free", "Notched"))
shrooms$GillAttachment[shrooms$GillAttachment == "a"] = "Attached"
shrooms$GillAttachment[shrooms$GillAttachment == "d"] = "Descending"
shrooms$GillAttachment[shrooms$GillAttachment == "f"] = "Free"
shrooms$GillAttachment[shrooms$GillAttachment == "n"] = "Notched"

# GillSpacing
levels(shrooms$GillSpacing) = c(levels(shrooms$GillSpacing), c("Close", "Crowded", "Distant"))
shrooms$GillSpacing[shrooms$GillSpacing == "c"] = "Close"
shrooms$GillSpacing[shrooms$GillSpacing == "w"] = "Crowded"
shrooms$GillSpacing[shrooms$GillSpacing == "d"] = "Distant"

# GillSize
levels(shrooms$GillSize) = c(levels(shrooms$GillSize), c("Broad", "Narrow"))
shrooms$GillSize[shrooms$GillSize == "b"] = "Broad"
shrooms$GillSize[shrooms$GillSize == "n"] = "Narrow"

# GillColor
levels(shrooms$GillColor) = c(levels(shrooms$GillColor), c("Black", "Brown", "Buff", "Chocolate", "Gray", "Green", "Orange", "Pink", "Purple", "Red", "White", "Yellow"))
shrooms$GillColor[shrooms$GillColor == "k"] = "Black"
shrooms$GillColor[shrooms$GillColor == "n"] = "Brown"
shrooms$GillColor[shrooms$GillColor == "b"] = "Buff"
shrooms$GillColor[shrooms$GillColor == "h"] = "Chocolate"
shrooms$GillColor[shrooms$GillColor == "g"] = "Gray"
shrooms$GillColor[shrooms$GillColor == "r"] = "Green"
shrooms$GillColor[shrooms$GillColor == "o"] = "Orange"
shrooms$GillColor[shrooms$GillColor == "p"] = "Pink"
shrooms$GillColor[shrooms$GillColor == "u"] = "Purple"
shrooms$GillColor[shrooms$GillColor == "e"] = "Red"
shrooms$GillColor[shrooms$GillColor == "w"] = "White"
shrooms$GillColor[shrooms$GillColor == "y"] = "Yellow"

# StalkShape
levels(shrooms$StalkShape) = c(levels(shrooms$StalkShape), c("Enlarging", "Tapering"))
shrooms$StalkShape[shrooms$StalkShape == "e"] = "Enlarging"
shrooms$StalkShape[shrooms$StalkShape == "t"] = "Tapering"

# StalkRoot
levels(shrooms$StalkRoot) = c(levels(shrooms$StalkRoot), c("Bulbous", "Club", "Cup", "Equal", "Rhizomorphs", "Rooted", "Missing"))
shrooms$StalkRoot[shrooms$StalkRoot == "b"] = "Bulbous"
shrooms$StalkRoot[shrooms$StalkRoot == "c"] = "Club"
shrooms$StalkRoot[shrooms$StalkRoot == "u"] = "Cup"
shrooms$StalkRoot[shrooms$StalkRoot == "e"] = "Equal"
shrooms$StalkRoot[shrooms$StalkRoot == "z"] = "Rhizomorphs"
shrooms$StalkRoot[shrooms$StalkRoot == "r"] = "Rooted"
shrooms$StalkRoot[shrooms$StalkRoot == "?"] = "Missing"

# StalkSurfaceAboveRing
levels(shrooms$StalkSurfaceAboveRing) = c(levels(shrooms$StalkSurfaceAboveRing), c("Fibrous", "Scaly", "Silky", "Smooth"))
shrooms$StalkSurfaceAboveRing[shrooms$StalkSurfaceAboveRing == "f"] = "Fibrous"
shrooms$StalkSurfaceAboveRing[shrooms$StalkSurfaceAboveRing == "y"] = "Scaly"
shrooms$StalkSurfaceAboveRing[shrooms$StalkSurfaceAboveRing == "k"] = "Silky"
shrooms$StalkSurfaceAboveRing[shrooms$StalkSurfaceAboveRing == "s"] = "Smooth"

# StalkSurfaceBelowRing
levels(shrooms$StalkSurfaceBelowRing) = c(levels(shrooms$StalkSurfaceBelowRing), c("Fibrous", "Scaly", "Silky", "Smooth"))
shrooms$StalkSurfaceBelowRing[shrooms$StalkSurfaceBelowRing == "f"] = "Fibrous"
shrooms$StalkSurfaceBelowRing[shrooms$StalkSurfaceBelowRing == "y"] = "Scaly"
shrooms$StalkSurfaceBelowRing[shrooms$StalkSurfaceBelowRing == "k"] = "Silky"
shrooms$StalkSurfaceBelowRing[shrooms$StalkSurfaceBelowRing == "s"] = "Smooth"

# StalkColorAboveRing
levels(shrooms$StalkColorAboveRing) = c(levels(shrooms$StalkColorAboveRing), c("Brown", "Buff", "Cinnamon", "Gray", "Orange", "Pink", "Red", "White", "Yellow"))
shrooms$StalkColorAboveRing[shrooms$StalkColorAboveRing == "n"] = "Brown"
shrooms$StalkColorAboveRing[shrooms$StalkColorAboveRing == "b"] = "Buff"
shrooms$StalkColorAboveRing[shrooms$StalkColorAboveRing == "c"] = "Cinnamon"
shrooms$StalkColorAboveRing[shrooms$StalkColorAboveRing == "g"] = "Gray"
shrooms$StalkColorAboveRing[shrooms$StalkColorAboveRing == "o"] = "Orange"
shrooms$StalkColorAboveRing[shrooms$StalkColorAboveRing == "p"] = "Pink"
shrooms$StalkColorAboveRing[shrooms$StalkColorAboveRing == "e"] = "Red"
shrooms$StalkColorAboveRing[shrooms$StalkColorAboveRing == "w"] = "White"
shrooms$StalkColorAboveRing[shrooms$StalkColorAboveRing == "y"] = "Yellow"

# StalkColorBelowRing
levels(shrooms$StalkColorBelowRing) = c(levels(shrooms$StalkColorBelowRing), c("Brown", "Buff", "Cinnamon", "Gray", "Orange", "Pink", "Red", "White", "Yellow"))
shrooms$StalkColorBelowRing[shrooms$StalkColorBelowRing == "n"] = "Brown"
shrooms$StalkColorBelowRing[shrooms$StalkColorBelowRing == "b"] = "Buff"
shrooms$StalkColorBelowRing[shrooms$StalkColorBelowRing == "c"] = "Cinnamon"
shrooms$StalkColorBelowRing[shrooms$StalkColorBelowRing == "g"] = "Gray"
shrooms$StalkColorBelowRing[shrooms$StalkColorBelowRing == "o"] = "Orange"
shrooms$StalkColorBelowRing[shrooms$StalkColorBelowRing == "p"] = "Pink"
shrooms$StalkColorBelowRing[shrooms$StalkColorBelowRing == "e"] = "Red"
shrooms$StalkColorBelowRing[shrooms$StalkColorBelowRing == "w"] = "White"
shrooms$StalkColorBelowRing[shrooms$StalkColorBelowRing == "y"] = "Yellow"

# VeilType
levels(shrooms$VeilType) = c(levels(shrooms$VeilType), c("Partial", "Universal"))
shrooms$VeilType[shrooms$VeilType == "p"] = "Partial"
shrooms$VeilType[shrooms$VeilType == "u"] = "Universal"

# VeilColor

```

```

levels(shrooms$VeilColor) = c(levels(shrooms$VeilColor), c("Brown","Orange","White","Yellow"))
shrooms$VeilColor[shrooms$VeilColor == "n"] = "Brown"
shrooms$VeilColor[shrooms$VeilColor == "o"] = "Orange"
shrooms$VeilColor[shrooms$VeilColor == "w"] = "White"
shrooms$VeilColor[shrooms$VeilColor == "y"] = "Yellow"

# RingNumber
levels(shrooms$RingNumber) = c(levels(shrooms$RingNumber), c("None","One","Two"))
shrooms$RingNumber[shrooms$RingNumber == "n"] = "None"
shrooms$RingNumber[shrooms$RingNumber == "o"] = "One"
shrooms$RingNumber[shrooms$RingNumber == "t"] = "Two"

# RingType
levels(shrooms$RingType) = c(levels(shrooms$RingType), c("Cobwebby","Evanescent","Flaring","Large","None","Pendant","Sheathing","Zone"))
shrooms$RingType[shrooms$RingType == "c"] = "Cobwebby"
shrooms$RingType[shrooms$RingType == "e"] = "Evanescent"
shrooms$RingType[shrooms$RingType == "f"] = "Flaring"
shrooms$RingType[shrooms$RingType == "l"] = "Large"
shrooms$RingType[shrooms$RingType == "n"] = "None"
shrooms$RingType[shrooms$RingType == "p"] = "Pendant"
shrooms$RingType[shrooms$RingType == "s"] = "Sheathing"
shrooms$RingType[shrooms$RingType == "z"] = "Zone"

# SporePrintColor
levels(shrooms$SporePrintColor) = c(levels(shrooms$SporePrintColor), c("Black","Brown","Buff","Chocolate","Green","Orange","Purple","White","Yellow"))
shrooms$SporePrintColor[shrooms$SporePrintColor == "k"] = "Black"
shrooms$SporePrintColor[shrooms$SporePrintColor == "n"] = "Brown"
shrooms$SporePrintColor[shrooms$SporePrintColor == "b"] = "Buff"
shrooms$SporePrintColor[shrooms$SporePrintColor == "h"] = "Chocolate"
shrooms$SporePrintColor[shrooms$SporePrintColor == "r"] = "Green"
shrooms$SporePrintColor[shrooms$SporePrintColor == "o"] = "Orange"
shrooms$SporePrintColor[shrooms$SporePrintColor == "u"] = "Purple"
shrooms$SporePrintColor[shrooms$SporePrintColor == "w"] = "White"
shrooms$SporePrintColor[shrooms$SporePrintColor == "y"] = "Yellow"

# Population
levels(shrooms$Population) = c(levels(shrooms$Population), c("Abundant","Clustered","Numerous","Scattered","Several","Solitary"))
shrooms$Population[shrooms$Population == "a"] = "Abundant"
shrooms$Population[shrooms$Population == "c"] = "Clustered"
shrooms$Population[shrooms$Population == "n"] = "Numerous"
shrooms$Population[shrooms$Population == "s"] = "Scattered"
shrooms$Population[shrooms$Population == "v"] = "Several"
shrooms$Population[shrooms$Population == "y"] = "Solitary"

# Habitat
levels(shrooms$Habitat) = c(levels(shrooms$Habitat), c("Grasses","Leaves","Meadows","Paths","Urban","Waste","Woods"))
shrooms$Habitat[shrooms$Habitat == "g"] = "Grasses"
shrooms$Habitat[shrooms$Habitat == "l"] = "Leaves"
shrooms$Habitat[shrooms$Habitat == "m"] = "Meadows"
shrooms$Habitat[shrooms$Habitat == "p"] = "Paths"
shrooms$Habitat[shrooms$Habitat == "u"] = "Urban"
shrooms$Habitat[shrooms$Habitat == "w"] = "Waste"
shrooms$Habitat[shrooms$Habitat == "d"] = "Woods"

return(shrooms)
}

```

Figure 5: clustData function for clustering Mushroom dataset

```

#Clustering Function
clustData <- function (df,ClassIndex,kmeansClasses = rep(0,unique(df[,ClassIndex]))) {
# use split function to split the dataset according to the class label
# a set of dataframes each representing a class label will be stored
# in dfs list()
dfs <- split (df, df[,ClassIndex])
# create empty list
clustList <- list()
n <- length(dfs)
for (i in 1:length(kmeansClasses)){
# Cluster according to all features excluding the label
if (kmeansClasses[i]>1 & kmeansClasses[i]< nrow(dfs[[i]])){
clustList[[i]] <- kmeans(dfs[[i]][,-ClassIndex],kmeansClasses[i])
#plotcluster(clustList[[i]], clustList[[i]]$cluster)
dfs[[i]]$cluster <- paste0((dfs[[i]][,ClassIndex]),
                           "_","c",clustList[[i]]$cluster)
}
else {
dfs[[i]]$cluster = paste0((dfs[[i]][,ClassIndex]),
                           "_c0")
}
}
# put all list elements in a dataframe and return it
# note that ldply() require the library plyr
allClusteredElements <- ldply (dfs, data.frame)
# drop the first column 'id' resulting from ldply
allClusteredElements <- allClusteredElements[,-1]
allClusteredElements <- allClusteredElements[,-ClassIndex]
return(allClusteredElements)
}

```