Project 3: Main Script

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This file firstly details the model selection process for an advanced binary classification model, that takes in images and classifies them as either a labradoodle (“1”) or fried chicken (“0”) - simply referred to as the Advanced Model. Secondly, it runs evaluation experiments to compare the Baseline Model - gradient boosting model (gbm) with parameters tuned on the original SIFT features - with our Advanced Model.

```
#Load (and install if necessary) required packages
if(!require("EBImage")){
  source("https://bioconductor.org/biocLite.R")
  biocLite("EBImage")
}
```

```
## Loading required package: EBImage
```

```
needed <- setdiff(c("gbm", "data.table", "e1071", "class", "adabag","caret"),
                  rownames(installed.packages()))
if (length(needed) > 0 ){
  install.packages(needed)
}
library(EBImage)
library(gbm)
```

```
## Loading required package: survival

## Loading required package: lattice

## Loading required package: splines

## Loading required package: parallel

## Loaded gbm 2.1.1
```

```
library(data.table)
```

```
##
## Attaching package: 'data.table'

## The following object is masked from 'package:EBImage':
##
##     transpose
```

```
library(e1071)
library(class)
library(adabag)
```

```
## Loading required package: rpart

## Loading required package: mlbench

## Loading required package: caret

## Loading required package: ggplot2

##
## Attaching package: 'caret'
## The following object is masked from 'package:survival':
##
##     cluster
```

```
library(caret)
```

Import class labels for training images

We code labradoodles as “1” and fried chicken as “0” for binary classification.

```
label_train <- read.csv("../data/train/labels.csv")
label_train <- as.matrix(label_train)[,1]
#some of our models require labels to be numeric in [0,1], so we keep the labels as 0's and 1's
#for any model that requires labels to be factors we pass the labels to the tune or train function
#specific to the model as numeric values and coerce them inside the function to be factors
```

Selecting the Advanced Model:

Model selection with provided SIFT features of training images

Import the SIFT features of the set of 2000 training images

```
train_sift <- read.csv("../data/train/sift_features.csv")
train_sift <- t(as.matrix(train_sift))
```

Tune parameters of each model via cross-validation

Set up control for tuning models under consideration based on the provided SIFT features of the training images.
+ (T/F) tune models under consideration based on provided SIFT features

```
###### T/F to reproduce the tuning process for all models considered ######
run.tune.sift = FALSE
```

- Parameter-tuning process:

```
#get summary tables of best tuned parameters for each model considered, i.e. lowest cv error
#6 columns: "Model", "Best_Param_1", "Best_Param_2", "Best_Param_3",
#            "Best_Error", "Training_Time"
#  - NA values for Best_Param_2 and/or Best_Param_3 if model has less than 3 params
#############################################################################################


#source("../lib/xgboost.R")
#source("../lib/svm.R")
#source("../lib/knn.R")
#source("../lib/AdaBag_AdaBoost.R")
#source("../lib/blgbm.R")

if(run.tune.sift) {
  source("../lib/xgboost.R")
  source("../lib/svm.R")
  source("../lib/knn.R")
  source("../lib/AdaBag_AdaBoost.R")
```

```r
  source("../lib/blgbm.R")

  summary.xgb <- tune.xgb(train_sift,label_train)
  #save(summary.xgb, file="output/summary_best_xgb.RData")

  summary.svm.lin <- tune.svm.lin(train_sift,label_train)
  #save(summary.svm.lin, file="output/summary_best_svm_lin.Rdata")

  summary.svm.rad <- tune.svm.rad(train_sift,label_train)
  #save(summary.svm.rad,file="output/summary_best_svm_rad.Rdata")

  summary.knn <- tune.knn(train_sift,label_train)
  #save(summary.knn, file="output/summary_best_knn.Rdata")

  summary.AdaBag <- tune.AdaBag(train_sift,label_train)
  #save(summary.AdaBag,file="output/summary_best_AdaBag2.Rdata")

  summary.AdaBoost.M1 <- tune.AdaBoost.M1(train_sift,label_train)
  #save(summary.AdaBoost.M1,file="output/summary_best_AdaBoost.M1.Rdata")

  summary.AdaBoost_SAMME <- tune.AdaBoost_SAMME(train_sift,label_train)
  #save(summary.AdaBoost_SAMME,file="output/summary_best_AdaBoost_SAMME.Rdata")

  summary.bl<- tune.bl(train_sift, label_train)
  #save(summary.bl,file="output/summary_best_blgbm.RData")
}
```

Summary Table: parameter-tuning process on original SIFT features

Summary table of *best* models (i.e. models with *best* parameters) tuned on original SIFT features of the training set via cross-validation, sorted by CV Error.

```r
library(data.table)
#load already produced summary tables for best tuned parameters for each model considered
load("../output/summary_best_xgb.RData")
load("../output/summary_best_svm_lin.Rdata")
load("../output/summary_best_svm_rad.Rdata")
load("../output/summary_best_knn.Rdata")

load("../output/summary_best_AdaBag2.Rdata")

load("../output/summary_best_AdaBoost.M1.Rdata")
load("../output/summary_best_AdaBoost_SAMME.Rdata")

load("../output/summary_best_blgbm.Rdata")

#6 columns: "Model", "Best_Param_1", "Best_Param_2", "Best_Param_3",
#            "Best_Error", "Training_Time"
#  - NA values for Best_Param_2 and/or Best_Param_3 if model has less than 3 params
summary1 <- rbind(summary.xgb, summary.svm.lin,
                  summary.svm.rad,
                  summary.AdaBag2, summary.AdaBoost.M1,
                  summary.AdaBoost_SAMME,
                  summary.knn,summary.bl)
```

```r
#sort table by Best_Error in ascending order
summary1 <- summary1[order(summary1$Best_Error)]

#add column for feature set models are tuned on
(summary1 <- data.table(summary1[,1], Features = rep("Original SIFT",8), summary1[,2:6]))
```

```
##                      Model      Features     Best_Param_1 Best_Param_2
## 1:                 XGBoost Original SIFT    max_depth = 5    eta = 0.5
## 2:                  BL GBM Original SIFT shrinkage = 0.16   ntrees= 64
## 3: SVM with linear kernel Original SIFT      cost = 5000           NA
## 4:                  AdaBag Original SIFT     mfinal = 100           NA
## 5:             AdaBoost.M1 Original SIFT      mfinal = 15           NA
## 6:          AdaBoost_SAMME Original SIFT      mfinal = 15           NA
## 7:                     KNN Original SIFT            k = 1           NA
## 8: SVM with Radial Kernel Original SIFT       cost = 500    gamma = 2
##     Best_Param_3   Best_Error Training_Time
## 1: nrounds = 169 5.267342e-05      49.148 s
## 2:            NA 2.365000e-01      15.234 s
## 3:            NA 2.520000e-01      73.452 s
## 4:            NA 2.915000e-01    1780.513 s
## 5:            NA 3.095000e-01     239.031 s
## 6:            NA 3.190000e-01     249.718 s
## 7:            NA 3.735000e-01            NA
## 8:            NA 4.020000e-01      73.638 s
```

```r
save(summary1,file="../output/summary_best_models1.Rdata")
```

Model selection with new visual features

Import sets of new visual features

```r
#import the three csv files - the three new sets of visual features
new_train_feat1 <- read.csv("../data/train/sift_features_resize+adaptive.csv")
new_train_feat1 <- t(as.matrix(new_train_feat1))

new_train_feat2 <- read.csv("../data/train/sift_features_resize.csv")
new_train_feat2 <- t(as.matrix(new_train_feat2))

new_train_feat3 <- read.csv("../data/train/sift_features_adaptive.csv")
new_train_feat3 <- t(as.matrix(new_train_feat3))
```

Tune parameters of each model via cross-validation

- Set up control for tuning models under consideration based on three new sets of features of the training images.

- (T/F) tune models under consideration based on three new sets of visual features

```r
###### T/F to reproduce the tuning process for all models considered ######
run.tune.new = FALSE
```

- Parameter-tuning process:

```r
if (run.tune.new){
  source("../lib/xgboost.R")
  source("../lib/blgbm.R")

  ###******* Tune for xgBoost
  #  1)tune on the first set of new visual features for the training images
  summary.xgb.new1 <- tune.xgb(new_train_feat1,label_train)
  #save(summary.xgb.new1,file="../output/summary_best_xgb_new1.Rdata")

  #  2)tune on the second set of new visual features for the training images
  summary.xgb.new2 <- tune.xgb(new_train_feat2,label_train)
  #save(summary.xgb.new2,file="../output/summary_best_xgb_new2.Rdata")

  #  3)tune on the third set of new visual features for the training images
  summary.xgb.new3 <- tune.xgb(new_train_feat3,label_train)
  #save(summary.xgb.new3,file="../output/summary_best_xgb_new3.Rdata")


  ###******* Tune for gbm
  #  1)tune on the first set of new visual features for the training images
  summary.gbm.new1 <- bl.tune(new_train_feat1,label_train)
  #save(summary.gbm.new1,file="../output/summary_best_gbm_new1.Rdata")

  #  2)tune on the second set of new visual features for the training images
  summary.gbm.new2 <- bl.tune(new_train_feat2,label_train)
  #save(summary.gbm.new2,file="../output/summary_best_gbm_new2.Rdata")

  #  3)tune on the third set of new visual features for the training images
  summary.gbm.new3 <- bl.tune(new_train_feat3,label_train)
  #save(summary.gbm.new3,file="../output/summary_best_gbm_new3.Rdata")

}
```

Summary Table: parameter-tuning process on new features

```r
#load Rdata files
load("../output/summary_best_xgb_new1.Rdata")
load("../output/summary_best_xgb_new2.Rdata")
load("../output/summary_best_xgb_new3.Rdata")
load("../output/summary_best_gbm_new1.Rdata")
load("../output/summary_best_gbm_new2.Rdata")
load("../output/summary_best_gbm_new3.Rdata")

summary2 <- rbind(summary.xgb.new1, summary.xgb.new2,
                  summary.xgb.new3, summary.gbm.new1,
                  summary.gbm.new2, summary.gbm.new3)
#sort table by Best_Error in ascending order
summary2 <- summary2[order(summary2$Best_Error)]

#add column for feature set models are tuned on
(summary2 <- data.table(summary2[,1], Features = c("SIFT- resize+adaptive","SIFT- resize",
                                                     "SIFT- adaptive", "SIFT- resize+adaptive",
                                                     "SIFT- resize", "SIFT- adaptive"),
                        summary2[,2:6]))
```

```
##      Model               Features     Best_Param_1 Best_Param_2
## 1: XGBoost SIFT- resize+adaptive    max_depth = 7    eta = 0.5
## 2:  BL GBM           SIFT- resize shrinkage = 0.21   ntrees= 48
## 3: XGBoost         SIFT- adaptive    max_depth = 7    eta = 0.2
## 4:  BL GBM SIFT- resize+adaptive shrinkage = 0.16  ntrees= 127
## 5:  BL GBM           SIFT- resize shrinkage = 0.21   ntrees= 46
## 6: XGBoost         SIFT- adaptive    max_depth = 7    eta = 0.2
##    Best_Param_3 Best_Error Training_Time
## 1: nrounds = 45     0.1890      19.032 s
## 2:           NA     0.1900      11.324 s
## 3: nrounds = 62     0.1905      26.374 s
## 4:           NA     0.1935      23.067 s
## 5:           NA     0.2470      12.802 s
## 6: nrounds = 44     0.2575      20.311 s
```

```
save(summary2,file="../output/summary_best_models2.Rdata")
```

Convolutional Neural Network (CNN)

Tune CNN model on set of raw training images via cross-validation

- Set up control for tuning CNN on set of raw images
- (T/F) tune CNN

```
###### T/F to reproduce the tuning process for all models considered ######
run.tune.cnn = FALSE
```

- Parameter-tuning process

```
if (run.tune.cnn) {
  img_train_dir <- "../data/train/raw_images"
  source("../lib/CNN.R")
  source("../lib/CNNcv.R")

  #first resize the raw images and then split into test set(200) and train set(1800)
  data_list <- to.resize.split(img_train_dir,label_train)


  #cross-validation on the resized train set (1800 images)
  iter <- seq(60,100,by=10) #iter is the range of the tune parameters
  #get best num.rounds
  best_num.rounds <- CNNcv(data_list$train_data,iter)

  #retrain data (1800 images) ; get run.time; and test error using test set(200 images)
  cnn.output <- CNN(data_list$train_data,data_list$test_data)

  summary.cnn <- data.table(Model = "CNN", Features = NA,
             Best_Param_1 = paste("num.rounds =",best_num.rounds),
             Best_Param_2 = NA,
             Best_Param_3 = NA,
             Best_Error = cnn.output$test_err,
             Training_Time = paste(cnn.output$train_time, "s"))
  #save(summary.cnn, file="output/summary_best_cnn.RData")

}
```

Selecting the *best* Advanced Model

Summary Table of best models tuned on various feature sets (original SIFT & new) + CNN

```
#load Rdata files
load("../output/summary_best_models1.Rdata")
load("../output/summary_best_models2.Rdata")

load("../output/summary_best_cnn.Rdata")

summary3 <- rbind(summary1,summary2,summary.cnn)
(summary3 <- summary3[order(summary3$Best_Error)])
```

```
##                       Model              Features     Best_Param_1
##  1:                 XGBoost         Original SIFT    max_depth = 5
##  2:                     CNN                    NA   num.round = 60
##  3:                 XGBoost SIFT- resize+adaptive    max_depth = 7
##  4:                  BL GBM          SIFT- resize shrinkage = 0.21
##  5:                 XGBoost        SIFT- adaptive    max_depth = 7
##  6:                  BL GBM SIFT- resize+adaptive shrinkage = 0.16
##  7:                  BL GBM         Original SIFT shrinkage = 0.16
##  8:                  BL GBM          SIFT- resize shrinkage = 0.21
##  9: SVM with linear kernel         Original SIFT      cost = 5000
## 10:                 XGBoost        SIFT- adaptive    max_depth = 7
## 11:                  AdaBag         Original SIFT     mfinal = 100
## 12:             AdaBoost.M1         Original SIFT      mfinal = 15
## 13:          AdaBoost_SAMME         Original SIFT      mfinal = 15
## 14:                     KNN         Original SIFT            k = 1
## 15: SVM with Radial Kernel         Original SIFT       cost = 500
##     Best_Param_2  Best_Param_3   Best_Error Training_Time
##  1:    eta = 0.5 nrounds = 169 5.267342e-05      49.148 s
##  2:           NA            NA 1.355000e-01    321.5955 s
##  3:    eta = 0.5  nrounds = 45 1.890000e-01      19.032 s
##  4:   ntrees= 48            NA 1.900000e-01      11.324 s
##  5:    eta = 0.2  nrounds = 62 1.905000e-01      26.374 s
##  6:  ntrees= 127            NA 1.935000e-01      23.067 s
##  7:   ntrees= 64            NA 2.365000e-01      15.234 s
##  8:   ntrees= 46            NA 2.470000e-01      12.802 s
##  9:           NA            NA 2.520000e-01      73.452 s
## 10:    eta = 0.2  nrounds = 44 2.575000e-01      20.311 s
## 11:           NA            NA 2.915000e-01    1780.513 s
## 12:           NA            NA 3.095000e-01     239.031 s
## 13:           NA            NA 3.190000e-01     249.718 s
## 14:           NA            NA 3.735000e-01            NA
## 15:    gamma = 2            NA 4.020000e-01      73.638 s
```

```
save(summary3,file="../output/summary_best_models3.Rdata")
save(summary3,file="../output/summary_best_models3.Rdata")
```

In the summary table, the models under consideration are ranked by best (min) error. The Baseline Model

(GBM with original SIFT) is ranked 7th with cross-validation estimated prediction error of .2365 and training time of 15.234 seconds. Model 1 in the table (XGBoost with original SIFT) has the lowest estimated prediction error of 5.267342e-05 (<<.2365), but it has a higher training time of 49.148 seconds (>15.234 seconds). Model 2 in the table (CNN with 1800 of the 2000 raw images) has an test error (testing with the remaining 200 of the 2000 raw images) of .1355, but it has a really large training time of 321.5955 seconds (>>15.234 seconds). Model 3 in the table (XGBoost with SIFT- resize+adaptive) has a decently low cross-validation estimated prediction error of .189 (<.2365) and a decently low training time of 19.032 seconds (only slightly larger, but comparable to 15.234 seconds). Thus, we chose Model 3 (XGBoost with SIFT- resize+adaptive) to be our advanced model, as it seems the best compromise between a low estimated prediction error and a small training time.

Comparing the Baseline Model and the Advanced Model

Set up controls for evaluation experiments: Baseline Model vs. Advanced Model

- (T/F) train Baseline Model and Advanced Model
- (T/F) process features for training set
- (T/F) run evaluation on an independent test set for both Baseline Model and Advanced Model
- (T/F) process features for test set

```
run.train=TRUE # train 'best' model
run.feature.train=TRUE # process features for training set
run.test=FALSE # run evaluation on an independent test set
run.feature.test=FALSE # process features for test set
```

Import given SIFT features new visual features of the test set

We construct the new visual features outside of R/Rstudio, so we just import the .csv files with the new feature data.

```
#Recall for the training set we imported the .csv files before
if (run.feature.train){
  #dat_train_sift <- read.csv("../data/train/sift_features.csv")
  #dat_train_sift <- t(as.matrix(dat_train_sift))
  dat_train_sift <- train_sift
  save(dat_train_sift,file="../output/dat_train_sift.Rdata")

  #dat_train_new <- read.csv("../data/train/sift_features_resize+adaptive.csv")
  #dat_train_new <- t(as.matrix(dat_train_new))
  dat_train_new <- new_train_feat1 #we selected new feature set 1: SIFT- resize+adaptive
  save(dat_train_new,file="../output/dat_train_new.Rdata")
}

##Now for the test set:
if (run.feature.test){
  #Import the provide SIFT features of the test set
  dat_test_sift <- read.csv("../data/test/sift_features_test.csv")
  dat_test_sift <- t(as.matrix(dat_test_sift))
  save(dat_test_sift,file="../output/dat_test_sift.Rdata")
  #Import the set of new visual features (constructed outside of R)
  dat_test_new <- read.csv("../data/test/sift_features_resize+adaptive.csv")  # ***or other file name
  dat_test_new <- t(as.matrix(dat_test_new))
  save(dat_test_new,file="../output/dat_test_new.Rdata")
}

#tm_feature_test = NA
```

Train a classification model with training images

`train.R` and `test.R` should be wrappers for all your model training steps and your classification/prediction steps. + `train.R` + Input: an R object that contains processed training set features. + Input: an R object of training sample labels. + Output: an RData file that contains trained classifiers in the forms of R objects: models/settings/links to external trained configurations. + `test.R` + Input: a path that points to the test set features. + Input: an R object that contains a trained classifiers. + Output: an R object of class label predictions on the test set. If there are multiple classifiers under evaluation, there should be multiple sets of label predictions.

```
source("../lib/train.R")
source("../lib/test.R")
```

Train Baseline Model and Advanced Model

Here we call the `train()` function in `train.R`. We fit the entire set of constructed visual features of the training images to the Baseline Model and the Advanced Model.

```
#Here, we call train() from train.R
#   -note that train() returns a list of two model objects: list(baseline_fit,advanced_fit)
tm_train=NA ; tm_train_base=NA ; tm_train_adv=NA
if(run.train){
  load(file="../output/dat_train_sift.Rdata")
  load(file="../output/dat_train_new.Rdata")
  tm_train <- system.time(fit_train <- train(dat_train_base = dat_train_sift,
                                             dat_train_adv = dat_train_new,
                                             label_train=label_train))
  save(fit_train, file="../output/fit_train.Rdata")

  #individual times for training base model and advanced model
  tm_train_base <- system.time(fit_train_base <- train(dat_train_base = dat_train_sift,
                                                       label_train=label_train, model="base"))
  tm_train_adv <- system.time(fit_train_adv <- train(dat_train_adv = dat_train_new,
                                                     label_train=label_train,model="advanced"))
}
```

```
## Loading required package: xgboost
```

Make predictions

Here we call the `test()` function in `test.R`. Feed the Baseline Model and the Advanced Model with the completely holdout testing data.

```
###############################################################################################
#to test the test() function, get predictions on training data for base model and advanced model
load(file="../output/fit_train.Rdata")
load(file="../output/dat_train_sift.Rdata")
load(file="../output/dat_train_new.Rdata")
```

```r
(pred_train <- test(fit_train = fit_train, dat_test_base = dat_train_sift,
                    dat_test_adv = dat_train_new))
```

```
## $baseline_pred
##    [1] 0 0 0 0 1 1 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0
##   [35] 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0 1 0 0 0 0
##   [69] 0 0 1 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 1 0
##  [103] 1 0 0 0 0 0 1 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 1 1 0 0 1 0 0 0 0 0 0 0
##  [137] 0 0 0 1 1 0 1 0 1 0 0 1 1 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0
##  [171] 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 1 0 0 0 0 1 0 0 0 0 0 0 0 0 1
##  [205] 0 0 0 1 0 1 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0 1 1 1 0 0 1 0 1 0 0 0 1 0
##  [239] 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 1 0 1 0 0 0 1 0 0 0 0 1 0 0 1 0 0 0 0
##  [273] 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 0 0 0 1 1 0 0
##  [307] 0 1 1 1 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0
##  [341] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 1 0 0 1
##  [375] 0 1 0 1 1 0 0 0 0 0 0 0 1 1 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1
##  [409] 0 0 0 0 0 1 1 1 0 0 0 0 0 1 0 0 0 0 0 1 0 1 1 0 0 1 0 0 0 0 1 0 0 0
##  [443] 1 1 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 1 0 0 0
##  [477] 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 1 1 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0
##  [511] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 1 0 1 0 0 0 1 0 1 0
##  [545] 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0
##  [579] 0 0 1 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 1
##  [613] 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0
##  [647] 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 1 0 1 0 0 0
##  [681] 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 1 0 0 0 0
##  [715] 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0
##  [749] 0 0 0 1 1 0 0 0 0 0 0 0 1 0 1 0 0 1 0 0 0 1 1 0 1 0 0 0 1 1 0 0 0 1
##  [783] 1 0 0 0 0 0 0 0 0 1 1 0 0 1 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 1 0 1 0 0
##  [817] 1 1 0 0 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [851] 0 0 0 1 1 0 0 1 1 1 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0
##  [885] 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0
##  [919] 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 1 0 0 1 0 0 0 0 0 0 0 0 1 0
##  [953] 0 0 0 1 0 1 0 1 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 0
##  [987] 0 1 0 0 0 0 0 1 0 0 1 0 0 0 1 0 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 0 1
## [1021] 1 1 1 0 1 0 1 1 0 1 1 1 0 1 1 1 1 1 1 0 1 1 1 0 1 1 1 1 1 0 1 0 0 1
## [1055] 0 1 1 1 1 1 1 1 1 1 1 0 1 1 0 1 1 1 1 0 1 1 0 1 1 1 1 1 0 0 1 1 1 1
## [1089] 1 1 0 1 0 1 0 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1
## [1123] 1 1 0 1 1 0 0 1 1 1 1 1 1 0 0 1 0 1 1 0 1 1 0 0 1 0 0 1 1 1 1 0 0 1
## [1157] 1 0 1 1 1 0 1 1 0 1 1 1 0 0 1 0 1 1 1 1 1 1 0 1 1 0 0 0 0 1 0 0 1 1
## [1191] 1 1 1 1 1 1 0 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 0 1 1 1 1 1 1 1 0 1 1 0
## [1225] 1 0 0 1 0 1 1 1 0 0 0 0 0 1 0 1 0 1 1 1 0 1 1 1 1 0 1 1 1 0 1 0 1 0
## [1259] 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 0 1 1 0 1 1 1 1 1 0 0 1 1 1 1 1
## [1293] 1 1 1 1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1 0 1 1 1 1 0 1 1 1 1 1 0 0 1 1
## [1327] 0 1 1 0 0 1 0 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 0 1 0 1 1 1
## [1361] 1 1 0 0 0 0 1 1 1 0 0 1 0 1 0 0 1 1 1 0 1 0 1 1 1 0 0 1 1 1 1 1 1 1
## [1395] 0 0 1 0 1 1 1 0 1 1 1 0 0 1 0 1 1 1 1 0 1 1 0 1 1 0 0 1 1 1 0 0 0 0
## [1429] 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 0 1 1 0 1 1 1 0 1 1 1 0 0 1 1
## [1463] 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 0 1 1 1 1 1 1 1 1 1 1 0 0 1 0
## [1497] 1 1 1 1 0 1 0 0 1 1 1 1 1 0 0 1 1 0 1 1 1 1 1 1 0 1 1 0 1 1 1 1 1 0
## [1531] 0 1 1 0 1 1 1 1 1 0 1 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1
## [1565] 1 1 0 1 1 0 1 1 0 0 1 0 0 1 1 1 0 0 1 1 0 1 1 0 0 0 0 0 1 1 1 1 1 1
## [1599] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 1 1 1 1 0 1 1 1 1 1 1 1
## [1633] 1 0 1 1 1 1 0 1 0 1 1 0 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1667] 1 0 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1
## [1701] 1 0 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 0 1 0 1 1 0 0 1 1 1 1
## [1735] 1 1 0 1 0 1 1 1 1 1 0 1 0 1 1 1 1 1 1 0 1 1 1 0 1 1 0 0 1 1 1 1 1 1
## [1769] 1 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1
## [1803] 1 1 1 1 0 0 0 0 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1837] 1 1 0 1 0 1 0 1 1 1 1 1 1 0 1 1 1 1 0 1 1 1 0 0 1 1 0 1 1 0 0 1 1 0
## [1871] 1 0 0 0 1 1 0 0 1 1 1 1 1 1 1 0 1 0 1 1 1 1 1 1 0 1 1 1 0 1 0 1 1 1
## [1905] 1 1 1 1 1 1 1 1 1 0 1 1 0 1 0 1 1 1 1 1 1 1 0 1 1 1 0 0 1 0 1 1 1 1
## [1939] 1 1 1 1 1 1 1 0 0 1 1 1 0 1 1 1 1 1 1 1 0 1 1 1 1 0 1 1 1 1 1 1 1 1
## [1973] 0 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
##
## $advanced_pred
##    [1] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##   [35] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##   [69] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [103] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [137] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [171] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [205] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [239] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [273] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [307] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [341] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [375] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [409] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [443] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [477] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [511] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [545] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [579] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [613] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [647] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [681] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [715] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [749] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [783] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [817] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [851] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [885] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [919] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [953] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [987] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1021] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1055] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1089] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1123] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1157] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1191] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1225] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1259] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1293] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1327] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1361] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1395] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1429] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1463] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1497] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1531] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1565] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1599] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1633] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1667] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1701] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1735] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1769] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1803] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1837] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1871] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1905] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1939] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1973] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

```r
#################################################################################################
#Make predictions and record the time it takes
tm_test=NA
if(run.test){
  load(file="../output/dat_test_sift.Rdata")
  load(file="../output/dat_test_new.Rdata")
  load(file="../output/fit_train.Rdata")
  tm_test <- system.time(pred_test <- test(fit_train = fit_train,
                                           dat_test_base = dat_test_sift,
                                           dat_test_adv = dat_test_new))
  save(pred_test, file="../output/pred_test.RData")

  #individual times for making predictions using base model and advanced model
  tm_test_base <- system.time(pred_test_base <- test(fit_train = fit_train_base,
                                                     dat_test_base = dat_test_sift,
                                                     model="base"))
  tm_test_adv <- system.time(pred_test_adv <- test(fit_train = fit_train_adv,
                                                   dat_test_adv = dat_test_new,
                                                   model="advanced"))
}
```

Summarize Running Time

Prediction performance matters, so does the running times for constructing features and for training the model, especially when the computation resource is limited.

```r
if(run.feature.train){
  load("../output/tm_new_feature_train.Rdata")   #tm_new_feature_train
  cat("Time for constructing new training features=", tm_new_feature_train[1], "s \n")
}
```

```
## Time for constructing new training features= 1163.52 s
```

```r
if (run.feature.test){
load("../output/tm_new_feature_test.Rdata")   #tm_new_feature_test
cat("Time for constructing new testing features=", tm_new_feature_test[1], "s \n")
}
if (run.train){
```

```
cat("Time for training models (Baseline + Advanced)=", tm_train[1], "s \n")
cat("Time for training Baseline Model=", tm_train_base[1], "s \n")
cat("Time for training Advanced Model=", tm_train_adv[1], "s \n")
}
```

```
## Time for training models (Baseline + Advanced)= 30.568 s
## Time for training Baseline Model= 10.394 s
## Time for training Advanced Model= 18.95 s
```

```
if(run.test){
cat("Time for making predictions (Baseline + Advanced)=", tm_test[1], "s \n")
cat("Time for making predictions with Baseline Model=", tm_test_base[1], "s \n")
cat("Time for making predictions with Advanced Model=", tm_test_adv[1], "s \n")
}
```