

# Classification and Regression Trees (CART)

Feature space partition ensemble model for replication (FESPAE)

EGG data-based experiments

**Article:** Lizbeth Naranjo, Carlos J. Perez, Daniel F. Merino (2025). A data ensemble-based approach for detecting vocal disorders using replicated acoustic biomarkers from electroglottography. *Sensing and Bio-Sensing Research Journal*, vol, num, pages.

```
library(tidyverse)
library(caret)
library(rpart)
## change the address where the file will be saved
address = "~/Documents/GitHub/"
setwd("~/Documents/GitHub/")
```

## EGG data-based experiments

```
## Comment or uncomment the options: EGG-a, EGG-i, EGG-u
```

```
## EGG-a
## datos2 <- read.csv(paste0(address,"a_egg_saarbrucken.csv"),
##                    sep = ";",header=TRUE, dec=",")

## name of the files to save results
## archivo = "FESPAE_crossval_strata_allvar_CART_Saarbrucken_egg_a"
```

```
## EGG-i
## datos2 <- read.csv(paste0(address,"i_egg_saarbrucken.csv"),
##                    sep = ";",header=TRUE, dec=",")

## name of the files to save results
## archivo = "FESPAE_crossval_strata_allvar_CART_Saarbrucken_egg_i"
```

```
## EGG-u
datos2 <- read.csv(paste0(address,"u_egg_saarbrucken.csv"),
                  sep = ";",header=TRUE, dec=",")

## name of the files to save results
archivo = "FESPAE_crossval_strata_allvar_CART_Saarbrucken_egg_u"
```

```
dim(datos2)
```

```
[1] 675 36
```

```
summary(datos2)
```

ID_fact	status_fact	SEX	JITTER
Min. : 1.0	Min. :0	Min. :0.0000	Min. : 0.00
1st Qu.:169.5	1st Qu.:0	1st Qu.:0.0000	1st Qu.: 0.45
Median :338.0	Median :1	Median :0.0000	Median : 1.06
Mean :338.0	Mean :1	Mean :0.4133	Mean : 13.84
3rd Qu.:506.5	3rd Qu.:2	3rd Qu.:1.0000	3rd Qu.: 17.95
Max. :675.0	Max. :2	Max. :1.0000	Max. :273.97
SHIMMER	CPP	D2	FZCF
Min. :0.00000	Min. :12.04	Min. : 2.000	Min. : 5.00
1st Qu.:0.03000	1st Qu.:18.02	1st Qu.: 3.625	1st Qu.: 11.00
Median :0.05000	Median :20.86	Median : 4.410	Median : 16.00
Mean :0.06012	Mean :21.36	Mean : 4.738	Mean : 42.47
3rd Qu.:0.08000	3rd Qu.:23.95	3rd Qu.: 5.445	3rd Qu.: 23.00
Max. :0.38000	Max. :34.19	Max. :18.380	Max. :5280.00
GENE	HNHR	HURST	LZ
Min. :0.4100	Min. : -3.94	Min. :0.1000	Min. : 19.0
1st Qu.:0.6350	1st Qu.:20.15	1st Qu.:0.6150	1st Qu.: 37.0
Median :0.8000	Median :23.48	Median :0.8700	Median : 50.0
Mean :0.9465	Mean :22.34	Mean :0.8806	Mean : 54.2
3rd Qu.:1.0950	3rd Qu.:26.51	3rd Qu.:1.1350	3rd Qu.: 65.5
Max. :5.0900	Max. :33.91	Max. :1.7700	Max. :279.0
MFCC0	MFCC1	MFCC2	MFCC3
Min. : -2.8800	Min. : -19.06	Min. : -30.610	Min. : -45.920
1st Qu.: -1.1200	1st Qu.: 11.15	1st Qu.: -0.635	1st Qu.: -21.495
Median : -0.5300	Median : 18.10	Median : 10.670	Median : -7.850
Mean : -0.5224	Mean : 16.26	Mean : 9.860	Mean : -8.324
3rd Qu.: 0.1200	3rd Qu.: 22.50	3rd Qu.: 19.775	3rd Qu.: 3.180
Max. : 2.0500	Max. : 32.80	Max. : 46.420	Max. : 48.690
MFCC4	MFCC5	MFCC6	MFCC7
Min. : -57.250	Min. : -43.400	Min. : -43.040	Min. : -41.830
1st Qu.: -20.330	1st Qu.: -14.910	1st Qu.: -15.365	1st Qu.: -16.115
Median : -10.640	Median : -7.710	Median : -8.610	Median : -8.020
Mean : -11.226	Mean : -7.712	Mean : -8.940	Mean : -8.249
3rd Qu.: -2.105	3rd Qu.: 0.945	3rd Qu.: -2.035	3rd Qu.: -0.215
Max. : 25.070	Max. : 34.400	Max. : 26.060	Max. : 36.600
MFCC8	MFCC9	MFCC10	MFCC11
Min. : -51.090	Min. : -47.06	Min. : -39.590	Min. : -39.150
1st Qu.: -15.975	1st Qu.: -13.44	1st Qu.: -12.060	1st Qu.: -12.575
Median : -7.810	Median : -6.26	Median : -4.420	Median : -4.380
Mean : -7.906	Mean : -5.64	Mean : -4.325	Mean : -4.466
3rd Qu.: -0.240	3rd Qu.: 1.71	3rd Qu.: 2.080	3rd Qu.: 2.885
Max. : 36.520	Max. : 40.73	Max. : 42.350	Max. : 35.350
MFCC12	PERMUTATION	PPE	SHANNON
Min. : -37.200	Min. : 1.110	Min. : 0.0000	Min. : 11.92
1st Qu.: -11.775	1st Qu.: 1.440	1st Qu.: 0.5300	1st Qu.: 12.16
Median : -5.020	Median : 1.570	Median : 0.5500	Median : 12.19
Mean : -4.221	Mean : 1.642	Mean : 0.5315	Mean : 12.18

3rd Qu.: 2.625	3rd Qu.:1.780	3rd Qu.:0.5700	3rd Qu.:12.21
Max. : 29.550	Max. :2.580	Max. :0.5700	Max. :12.26
ZCR	energyentropy	spectralcentroid	spectralspread
Min. :0.01000	Min. :2.500	Min. :0.0700	Min. :0.1200
1st Qu.:0.02000	1st Qu.:3.260	1st Qu.:0.1100	1st Qu.:0.1600
Median :0.03000	Median :3.310	Median :0.1200	Median :0.1800
Mean :0.03846	Mean :3.269	Mean :0.1206	Mean :0.1798
3rd Qu.:0.05000	3rd Qu.:3.320	3rd Qu.:0.1300	3rd Qu.:0.1900
Max. :0.20000	Max. :3.320	Max. :0.3300	Max. :0.3300
spectralentropy	spectralrolloff	RPDE	rep
Min. :0.0000	Min. :0.01000	Min. :0.0100	Min. :1
1st Qu.:0.0500	1st Qu.:0.04000	1st Qu.:0.2000	1st Qu.:1
Median :0.1100	Median :0.05000	Median :0.2800	Median :2
Mean :0.1832	Mean :0.05613	Mean :0.3194	Mean :2
3rd Qu.:0.2400	3rd Qu.:0.07000	3rd Qu.:0.3900	3rd Qu.:3
Max. :1.6400	Max. :0.37000	Max. :0.9000	Max. :3

```
head(datos2)
```

	ID_fact	status_fact	SEX	JITTER	SHIMMER	CPP	D2	FZCF	GNE	HNR	HURST	LZ	
1	1		0	0	0.21	0.02	28.48	4.35	25	0.63	27.12	1.20	32
2	2		0	0	0.43	0.06	22.18	3.23	31	0.58	18.23	1.38	44
3	3		0	0	0.46	0.03	24.91	5.24	27	0.60	24.93	1.30	33
4	4		0	0	0.49	0.02	31.64	3.14	24	0.57	25.71	1.17	34
5	5		0	0	11.39	0.09	24.74	2.16	40	0.43	15.64	1.51	39
6	6		0	0	0.33	0.03	29.29	3.27	33	0.47	24.57	1.40	33
	MFCC0	MFCC1	MFCC2	MFCC3	MFCC4	MFCC5	MFCC6	MFCC7	MFCC8	MFCC9	MFCC10	MFCC11	
1	-0.41	8.69	-0.89	0.03	3.66	-0.03	-0.20	-3.42	-4.11	-6.53	-8.78	-9.64	
2	-1.47	3.10	15.86	5.73	9.91	4.40	4.72	0.60	2.27	-2.16	-3.27	-3.26	
3	-0.92	7.38	11.85	2.93	2.55	2.91	3.56	-1.11	-1.74	-4.55	-4.97	-7.97	
4	-0.52	8.81	-2.68	2.83	-0.76	-0.60	-2.30	-5.78	-4.10	-7.55	-7.57	-8.92	
5	-2.06	11.23	9.58	5.36	7.67	2.17	3.94	4.12	4.38	0.62	0.97	1.00	
6	-1.39	14.83	3.50	-2.30	9.86	2.90	1.00	6.24	-1.52	1.44	-0.26	-1.19	
	MFCC12	PERMUTATION	PPE	SHANNON	ZCR	energyentropy	spectralcentroid						
1	-11.13		2.02	0.55	12.19	0.02	3.31				0.13		
2	-3.81		2.26	0.48	12.20	0.02	3.27				0.12		
3	-5.99		1.99	0.55	12.21	0.02	3.30				0.12		
4	-8.74		1.68	0.55	12.17	0.02	3.31				0.12		
5	-0.09		1.84	0.44	12.19	0.01	3.19				0.09		
6	-1.26		1.64	0.53	12.17	0.01	3.28				0.11		
	spectralspread	spectralentropy	spectralrolloff	RPDE	rep								
1		0.19		0.11		0.02	0.21		1				
2		0.21		0.06		0.02	0.50		2				
3		0.21		0.06		0.02	0.32		3				
4		0.18		0.13		0.03	0.32		1				
5		0.17		0.03		0.01	0.58		2				
6		0.18		0.08		0.02	0.37		3				

## Re-Scale explanatory variables

```
## Scale the variables
datos2 <- as.data.frame(datos2)
datos2$STATUS_fact = as.factor(as.numeric(factor(datos2$status_fact)))

table(datos2$STATUS_fact)
```

```
  1    2    3
225 225 225
```

```
datos <- transform(datos2,
sJITTER= scale(JITTER), sSHIMMER= scale(SHIMMER), sCPP= scale(CPP),
sD2= scale(D2), sFZCF= scale(FZCF), sGNE= scale(GNE),
sHNR= scale(HNR), sHURST= scale(HURST), sLZ= scale(LZ),
sMFCC0= scale(MFCC0),
sMFCC1= scale(MFCC1), sMFCC2= scale(MFCC2), sMFCC3= scale(MFCC3),
sMFCC4= scale(MFCC4), sMFCC5= scale(MFCC5), sMFCC6= scale(MFCC6),
sMFCC7= scale(MFCC7), sMFCC8= scale(MFCC8), sMFCC9= scale(MFCC9),
sMFCC10= scale(MFCC10), sMFCC11= scale(MFCC11), sMFCC12= scale(MFCC12),
sPERMUTATION= scale(PERMUTATION), sPPE= scale(PPE), sSHANNON= scale(SHANNON),
sZCR= scale(ZCR),
senenergyentropy= scale(energyentropy), sspectralcentroid= scale(spectralcentroid),
sspectralspread= scale(spectralspread), sspectralentropy= scale(spectralentropy),
sspectralrolloff= scale(spectralrolloff), sRPDE= scale(RPDE))

datos$ID_fact = rep(1:225,each=3)

dim(datos)
```

```
[1] 675  69
```

```
## data set
trainc <- datos %>% select(
sJITTER, sSHIMMER, sCPP, sD2, sFZCF,
sGNE, sHNR, sHURST, sLZ, sMFCC0,
sMFCC1, sMFCC2, sMFCC3, sMFCC4, sMFCC5,
sMFCC6, sMFCC7, sMFCC8, sMFCC9, sMFCC10,
sMFCC11, sMFCC12,
sPERMUTATION, sPPE, sSHANNON, sZCR,
senenergyentropy, sspectralcentroid, sspectralspread,
sspectralentropy, sspectralrolloff, sRPDE,
STATUS_fact,SEX, rep,ID_fact)
```

# Crossvalidation

## Subspaces

```
## Partition of subspaces
## The feature space is randomly partitioned into K subspaces with roughly equal sizes
## k = number of predictors
## K = subspaces

K0 = 4 ## sub-spaces
k = 32 ## explanatory variables
k2 = round(k/K0)
space = 1:k
subspaces = rep(list(rep(NA,k2)),K0) ## Subspaces
set.seed(12345)
for(j in 1:(K0-1)){
  space1 = sample(space, size=k2, replace=FALSE)
  space = setdiff(space,space1)
  subspaces[[j]] = space1[order(space1)]
}
space1 = space
subspaces[[K0]] = space1[order(space1)]
## 32 features = 1x32, 2x16, 4x8,
subspaces
```

```
## [[1]]
## [1] 11 14 16 19 24 26 28 29
##
## [[2]]
## [1] 2 6 7 10 12 21 30 32
##
## [[3]]
## [1] 1 4 5 9 13 15 27 31
##
## [[4]]
## [1] 3 8 17 18 20 22 23 25
```

## Training and testing data subsets

```
## Select data: 75% training & 25% testing stratified per category
SIM = 100  ## repeat N times the cross-validation process
N = 225  ## sample size
Nfit = 168  ## sample size for training subset
Ntest = 57  ## sample size for testing subset
Ncat = 75  ## sample size per category
Ncatfit = 56  ## training per category
Ncattest = 19  ## testing per category
FIT <- matrix(0,SIM,Nfit)  ## training subsets
TEST <- matrix(0,SIM,Ntest)  ## testing subsets

categoria = trainc %>% filter(rep==1) %>% select(STATUS_fact)
categoria = as.numeric(categoria$STATUS_fact)
id = 1:N
set.seed(12345)
for(si in 1:SIM){
  for(j in 1:3){
    idcat = id[categoria==j]  ## stratified per category j
    ran0 = sample(idcat, size=Ncatfit, replace=FALSE)

    FIT[si,(j-1)*Ncatfit+1:Ncatfit] <- sort(ran0)
    TEST[si,(j-1)*Ncattest+1:Ncattest] <- setdiff(idcat,ran0)
  }
}
```

## Classification metrics for models predicting nominal outcomes

```
## Functions to compute classification metrics
## Ytrue = true response variable
## Ypred = predicted outcome
## cat = category
## TP = true positive
## TN = true negative
## FP = false positive
## FN = false negative

## Function to compute the precision per class=cat
fn_precision_class <- function(Ytrue,Ypred,cat){
  TP = sum(Ypred[Ytrue==cat]==cat)
  FP = sum(Ypred[Ytrue!=cat]==cat)
  precision = TP/(TP+FP)
  return(precision)
}

## Function to compute the recall per class=cat
fn_recall_class <- function(Ytrue,Ypred,cat){ ## cat==category
  TP = sum(Ypred[Ytrue==cat]==cat)
  FN = sum(Ypred[Ytrue==cat]!=cat)
  recall = TP/(TP+FN)
  return(recall)
}

## Function to compute the F1-score per class=cat
fn_f1score_class <- function(Ytrue,Ypred,cat){ ## cat==category
  TP = sum(Ypred[Ytrue==cat]==cat)
  FP = sum(Ypred[Ytrue!=cat]==cat)
  FN = sum(Ypred[Ytrue==cat]!=cat)
  precision = TP/(TP+FP)
  recall = TP/(TP+FN)
  f1score = 2*(precision*recall)/(precision+recall)
  return(f1score)
}

## To save classification metrics
## Fitxxx: metric for training subset. Testxxx: metric for testing subset
FitAccuracy = TestAccuracy <- array(NA,dim=c(SIM,1)) ## Accuracy Rate
FitPrecisionClass = TestPrecisionClass <- array(NA,dim=c(SIM,1,3)) ## Precision per class
FitRecallClass = TestRecallClass <- array(NA,dim=c(SIM,1,3)) ## Recall per class
FitF1ScoreClass = TestF1ScoreClass <- array(NA,dim=c(SIM,1,3)) ## F1-score per class
FitPrecisionMacroAve = TestPrecisionMacroAve <- array(NA,dim=c(SIM,1)) ## Precision Macro Average
FitRecallMacroAve = TestRecallMacroAve <- array(NA,dim=c(SIM,1)) ## Recall Macro Average
FitF1ScoreMacroAve = TestF1ScoreMacroAve <- array(NA,dim=c(SIM,1)) ## F1-score Macro Average
```

## Model estimation

```
##-----BEGIN
for(sim in 1:SIM){ ### BEGIN sim
##-----

my_fit = FIT[sim,]    ## training subset
my_test = TEST[sim,]  ## testing subset

## Training data subset
train1 <- trainc %>% filter(ID_fact%in%my_fit, rep==1) ## repetition=1
train2 <- trainc %>% filter(ID_fact%in%my_fit, rep==2) ## repetition=2
train3 <- trainc %>% filter(ID_fact%in%my_fit, rep==3) ## repetition=3

Yc = train1$STATUS_fact    ## categorical response variable for training
n = length(Yc)
G = 3 # classes

## Testing data subset
test1 <- trainc %>% filter(ID_fact%in%my_test, rep==1) ## repetition=1
test2 <- trainc %>% filter(ID_fact%in%my_test, rep==2) ## repetition=2
test3 <- trainc %>% filter(ID_fact%in%my_test, rep==3) ## repetition=3

Yc.new = test1$STATUS_fact    ## categorical response variable for testing
n.new = length(Yc.new)

## Delete variables which are not used
train1 <- train1 %>% select(-c(rep,ID_fact))
train2 <- train2 %>% select(-c(rep,ID_fact))
train3 <- train3 %>% select(-c(rep,ID_fact))
test1 <- test1 %>% select(-c(rep,ID_fact))
test2 <- test2 %>% select(-c(rep,ID_fact))
test3 <- test3 %>% select(-c(rep,ID_fact))

##-----
## Algorithm FESPAE
## Feature space partition ensemble model for replication
##-----

## Algo1: The feature space is randomly partitioned into M subspaces, {S1,S2,...,SM}

K0 = 4 ## sub-spaces
k = 32 ## explanatory variables
k2 = round(k/K0)
space = 1:k
subspaces = rep(list(rep(NA,k2)),K0) ## Subspaces
set.seed(12345)
for(j in 1:(K0-1)){
  space1 = sample(space, size=k2, replace=FALSE)
  space = setdiff(space,space1)
  subspaces[[j]] = space1[order(space1)]
}
```



```

space1 = space
subspaces[[K0]] = space1[order(space1)]
# 32 features = 1x32, 2x16, 4x8,

##-----
## Algo2: for feature subspace m = 1 to M do

pred.vgam = array(NA,dim=c(n,G,K0,3)) ### 3 repeticiones
pred.new.vgam = array(NA,dim=c(n.new,G,K0,3)) ### 3 repeticiones
##-----
## Algo3: for replication j = 1 to J do

## REPLICATION j=1:
for(parti1 in 1:K0){ ## partition of the subspaces
train1_par = train1[,c(subspaces[[parti1]],k+1)]
test1_par = test1[,c(subspaces[[parti1]],k+1)]

## Algo4: Fit a classifier  $T(x_j, z)$ ,  $x_j$  in  $S_m$ , to the training data
mod1 <- rpart( STATUS_fact ~ . ,
               data = train1_par)
## summary(mod1)

## Algo5: Compute the C response probabilities  $\{\pi^{(m,j)}_{ic}\}$ , for  $i=1, \dots, n$ .
## Predictions
predict1.vgam <- predict(mod1, newdata = train1_par)
predict1.new.vgam <- predict(mod1, newdata = test1_par)

pred.vgam[, , parti1, 1] = predict1.vgam
pred.new.vgam[, , parti1, 1] = predict1.new.vgam
}

## REPLICATION j=2:
for(parti2 in 1:K0){ ## partition of the subspaces
train2_par = train2[,c(subspaces[[parti2]],k+1)]
test2_par = test2[,c(subspaces[[parti2]],k+1)]

## Algo4: Fit a classifier  $T(x_j, z)$ ,  $x_j$  in  $S_m$ , to the training data
mod2 <- rpart( STATUS_fact ~ . ,
               data = train2_par)
## summary(mod2)

## Algo5: Compute the C response probabilities  $\{\pi^{(m,j)}_{ic}\}$ , for  $i=1, \dots, n$ .
## Predictions
predict2.vgam <- predict(mod2, newdata = train2_par)
predict2.new.vgam <- predict(mod2, newdata = test2_par)

pred.vgam[, , parti2, 2] = predict2.vgam
pred.new.vgam[, , parti2, 2] = predict2.new.vgam
}

## REPLICATION j=3:
for(parti3 in 1:K0){ ## partition of the subspaces
train3_par = train3[,c(subspaces[[parti3]],k+1)]

```

```

test3_par = test3[,c(subspaces[[parti3]],k+1)]

## Algo4: Fit a classifier  $T(x_j, z)$ ,  $x_j \in S_m$ , to the training data
mod3 <- rpart( STATUS_fact ~ . ,
              data = train3_par)
## summary(mod3)

## Algo5: Compute the  $C$  response probabilities  $\{\pi^{(m,j)}_{ic}\}$ , for  $i=1, \dots, n$ .
## Predictions
predict3.vgam <- predict(mod3, newdata = train3_par)
predict3.new.vgam <- predict(mod3, newdata = test3_par)

pred.vgam[, , parti3, 3] = predict3.vgam
pred.new.vgam[, , parti3, 3] = predict3.new.vgam
}

##-----
## Algo6: End for replication  $j = 1$  to  $J$ 
## Algo7: End for feature subspace  $m = 1$  to  $M$ 
##-----
## Algo8: Output: compute the response probabilities  $\pi_{ic} = \text{mean}(\{\pi^{(m,j)}_{ic}\})$ 

pred.ave.vgam = apply(pred.vgam, c(1,2), mean)

### Predict new subjects
pred.ave.new.vgam = apply(pred.new.vgam, c(1,2), mean)

##-----
## Algo8: Output: compute the response category  $T^*(x, z) = \arg \max \{\pi_{ic}\}$ 

pred.vgam_max <- apply(pred.ave.vgam, 1, which.max)

### Predict new subjects
pred.new.vgam_max <- apply(pred.ave.new.vgam, 1, which.max)

##-----
## End FESPAE
##-----
## Classification Metrics for models predicting nominal outcomes

## Accuracy Rate
FitAccuracy[sim,] = c(sum(Yc==pred.vgam_max)/n)

TestAccuracy[sim,] = c(sum(Yc.new==pred.new.vgam_max)/n.new)

## Precision
for(cate in 1:3){
  FitPrecisionClass[sim,1, cate] = fn_precision_class(Yc, pred.vgam_max, cate)
  TestPrecisionClass[sim,1, cate] = fn_precision_class(Yc.new, pred.new.vgam_max, cate)
}
FitPrecisionMacroAve[sim, 1] = mean(FitPrecisionClass[sim, 1,])
TestPrecisionMacroAve[sim,1] = mean(TestPrecisionClass[sim,1,])

```

```

## Recall
for(cate in 1:3){
  FitRecallClass[sim,1, cate] = fn_recall_class(Yc, pred.vgam_max, cate)
  TestRecallClass[sim,1, cate] = fn_recall_class(Yc.new, pred.new.vgam_max, cate)
}
FitRecallMacroAve[sim, 1] = mean(FitRecallClass[sim, 1,])
TestRecallMacroAve[sim,1] = mean(TestRecallClass[sim,1,])

## F1-Score
for(cate in 1:3){
  FitF1ScoreClass[sim,1, cate]= fn_f1score_class(Yc, pred.vgam_max, cate)
  TestF1ScoreClass[sim,1, cate] = fn_f1score_class(Yc.new, pred.new.vgam_max, cate)
}
FitF1ScoreMacroAve[sim, 1] = mean(FitF1ScoreClass[sim, 1,])
TestF1ScoreMacroAve[sim,1] = mean(TestF1ScoreClass[sim,1,])

##-----
} ## END sim
##-----

```

# Results

## Accuracy Rate

```
columna = c("ensemble")
renglon = c("fit_mean", "fit_sd", "test_mean", "test_sd")

summary(FitAccuracy)
```

```
##           V1
##  Min.      :0.8869
## 1st Qu.:0.9167
##  Median :0.9345
##   Mean   :0.9321
## 3rd Qu.:0.9464
##   Max.   :0.9702
```

```
apply(FitAccuracy, 2, "sd")
```

```
## [1] 0.01768597
```

```
summary(TestAccuracy)
```

```
##           V1
##  Min.      :0.4561
## 1st Qu.:0.5614
##  Median :0.6140
##   Mean   :0.6125
## 3rd Qu.:0.6535
##   Max.   :0.7544
```

```
apply(TestAccuracy, 2, "sd")
```

```
## [1] 0.06323538
```

```
RESaccuracy <- rbind(apply(FitAccuracy, 2, "mean"), apply(FitAccuracy, 2, "sd"),
                    apply(TestAccuracy, 2, "mean"), apply(TestAccuracy, 2, "sd"))
colnames(RESaccuracy) = columna
rownames(RESaccuracy) = renglon
write.csv(RESaccuracy, file=paste0(archivo, "_accuracy", ".csv"))
```

## Precision Macro Average

```
summary(FitPrecisionMacroAve)
```

```
##          V1
##  Min.    :0.8894
## 1st Qu.:0.9205
##  Median :0.9347
##   Mean  :0.9334
## 3rd Qu.:0.9465
##   Max.   :0.9706
```

```
apply(FitPrecisionMacroAve,2,"sd")
```

```
## [1] 0.01718282
```

```
summary(TestPrecisionMacroAve)
```

```
##          V1
##  Min.    :0.4624
## 1st Qu.:0.5884
##  Median :0.6340
##   Mean  :0.6283
## 3rd Qu.:0.6734
##   Max.   :0.7743
```

```
apply(TestPrecisionMacroAve,2,"sd")
```

```
## [1] 0.06543121
```

```
RESprecision <- rbind(apply(FitPrecisionMacroAve,2,"mean"), apply(FitPrecisionMacroAve,2,"sd"),
                      apply(TestPrecisionMacroAve,2,"mean"), apply(TestPrecisionMacroAve,2,"sd"))
colnames(RESprecision) = columna
rownames(RESprecision) = renglon
write.csv(RESprecision, file=paste0(archivo,"_precision",".csv"))
```

## Recall Macro Average

```
summary(FitRecallMacroAve)
```

```
##          V1
##  Min.    :0.8869
## 1st Qu.:0.9167
##  Median :0.9345
##   Mean   :0.9321
## 3rd Qu.:0.9464
##   Max.   :0.9702
```

```
apply(FitRecallMacroAve,2,"sd")
```

```
## [1] 0.01768597
```

```
summary(TestRecallMacroAve)
```

```
##          V1
##  Min.    :0.4561
## 1st Qu.:0.5614
##  Median :0.6140
##   Mean   :0.6125
## 3rd Qu.:0.6535
##   Max.   :0.7544
```

```
apply(TestRecallMacroAve,2,"sd")
```

```
## [1] 0.06323538
```

```
RESrecall <- rbind(apply(FitRecallMacroAve,2,"mean"), apply(FitRecallMacroAve,2,"sd"),
                    apply(TestRecallMacroAve,2,"mean"),apply(TestRecallMacroAve,2,"sd"))
colnames(RESrecall) = columna
rownames(RESrecall) = renglon
write.csv(RESrecall, file=paste0(archivo,"_recall",".csv"))
```

## F1-Score Macro Average

```
summary(FitF1ScoreMacroAve)
```

```
##          V1
##  Min.    :0.8870
## 1st Qu.:0.9171
##  Median :0.9345
##   Mean   :0.9322
## 3rd Qu.:0.9463
##   Max.   :0.9702
```

```
apply(FitF1ScoreMacroAve,2,"sd")
```

```
## [1] 0.01763201
```

```
summary(TestF1ScoreMacroAve)
```

```
##          V1
##  Min.    :0.4529
## 1st Qu.:0.5662
##  Median :0.6137
##   Mean   :0.6120
## 3rd Qu.:0.6542
##   Max.   :0.7549
```

```
apply(TestF1ScoreMacroAve,2,"sd")
```

```
## [1] 0.0633796
```

```
RESf1score <- rbind(apply(FitF1ScoreMacroAve,2,"mean"), apply(FitF1ScoreMacroAve,2,"sd"),
                    apply(TestF1ScoreMacroAve,2,"mean"), apply(TestF1ScoreMacroAve,2,"sd"))
colnames(RESf1score) = columna
rownames(RESf1score) = renglon
write.csv(RESf1score, file=paste0(archivo,"_f1score",".csv"))
```