ANOVA and Paired Design

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Contents

ANOVA test

Começo a análise carregando o data.frame com os dados, seguindo para a aplicação do teste ANOVA e finalizando com o uso do Tukey teste.

```
#Taking a look at the data
summary(finalData)
```

```
##  loglikeValues                  model     depths      years
##  Min.   :-3158   gaModel           :720   100:1440   2005:720
##  1st Qu.:-2079   lista             :720   25 :1440   2006:720
##  Median :-1679   hybrid_gaModel    :720   60 :1440   2007:720
##  Mean   :-1702   hybrid_listaGA_New:720              2008:720
##  3rd Qu.:-1602   gaModelCluster    :720              2009:720
##  Max.   : -800   listaCluster      :720              2010:720
##       regions
##  Kanto    :1080
##  Kansai   :1080
##  Tohoku   :1080
##  EastJapan:1080
##
##
```

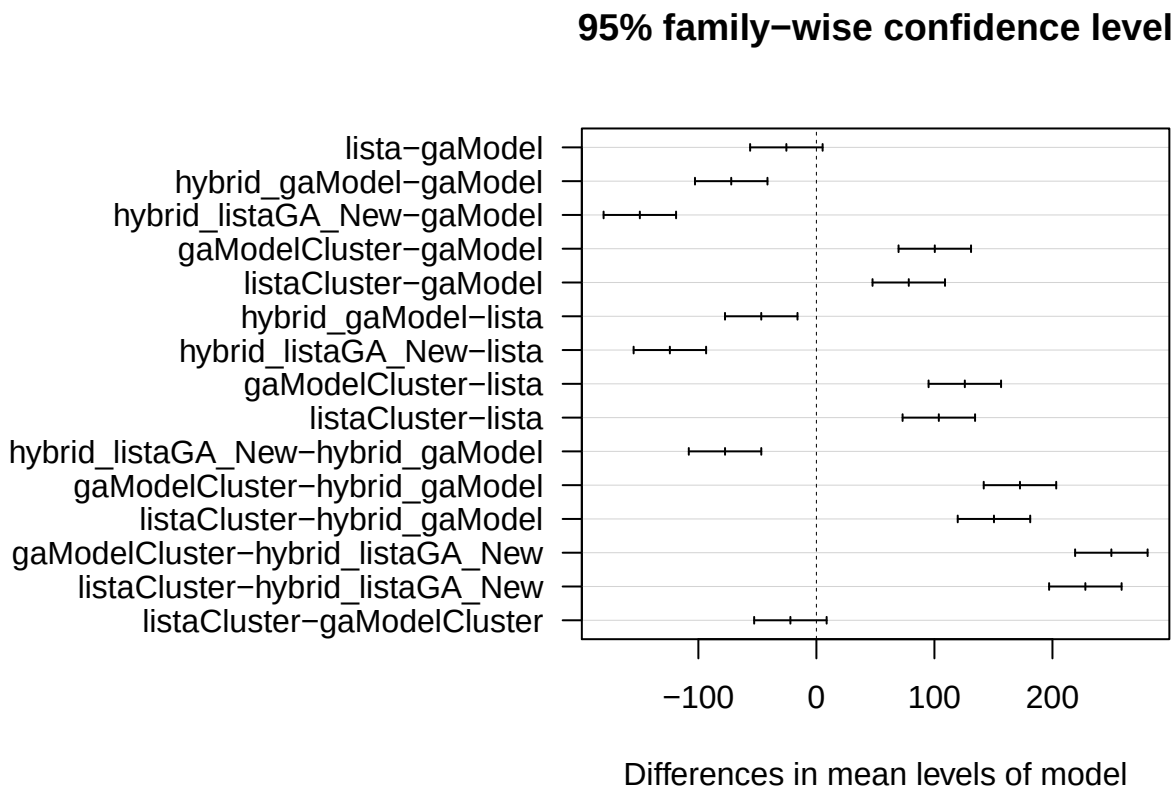
```
#Primeira vez aplicando ANOVA
resultANOVA = aov(loglikeValues~model+depths+years+regions , data = finalData)
summary(resultANOVA)
```

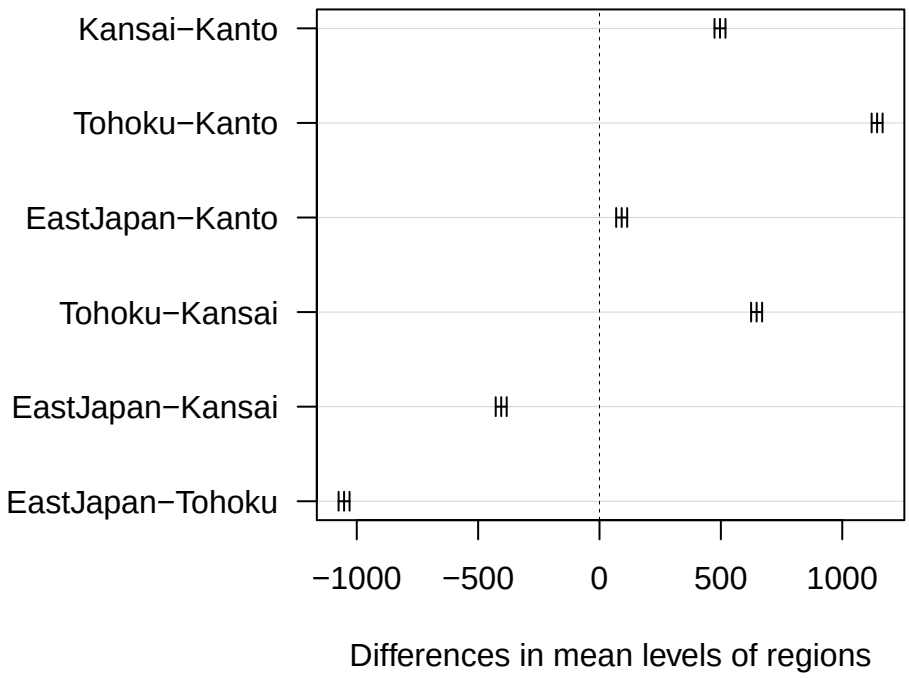
```
##               Df    Sum Sq   Mean Sq F value Pr(>F)
## model          5  31424058   6284812   255.0 <2e-16 ***
## depths         2  16077491   8038746   326.2 <2e-16 ***
## years          5  57908014  11581603   470.0 <2e-16 ***
## regions        3 878253346 292751115 11879.4 <2e-16 ***
## Residuals   4304 106066400     24644
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
#Segunda vez aplicando ANOVA, como a variável years influencia menos os dados foram removidos do teste
resultANOVA = aov(loglikeValues~model+regions , data = finalData)
summary(resultANOVA)
```

```
##               Df    Sum Sq   Mean Sq F value Pr(>F)
## model          5  31424058   6284812   150.5 <2e-16 ***
## regions        3 878253346 292751115  7009.4 <2e-16 ***
## Residuals   4311 180051906     41766
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
#Especificando quais são os grupos que diferem
tuk = TukeyHSD(resultANOVA)
#Variáveis para configuração do gráfico
# par(mfrow=c(2,2))
op <- par(mar = c(5,15,4,2) + 0.1)
#Função para gerar o gráfico
plot(tuk,las=1)
```






```
#Mostrando os resultados também em texto
print(tuk)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = loglikeValues ~ model + regions, data = finalData)
##
## $model
##                                       diff        lwr         upr
## lista-gaModel                     -25.44743  -56.15563    5.260775
## hybrid_gaModel-gaModel            -72.18184 -102.89005  -41.473643
## hybrid_listaGA_New-gaModel       -149.60620 -180.31441 -118.898003
## gaModelCluster-gaModel            100.31468   69.60648  131.022879
## listaCluster-gaModel               78.27546   47.56726  108.983663
## hybrid_gaModel-lista              -46.73442  -77.44262  -16.026217
## hybrid_listaGA_New-lista         -124.15878 -154.86698  -93.450577
## gaModelCluster-lista              125.76210   95.05390  156.470306
## listaCluster-lista                103.72289   73.01469  134.431089
## hybrid_listaGA_New-hybrid_gaModel  -77.42436 -108.13256  -46.716158
## gaModelCluster-hybrid_gaModel     172.49652  141.78832  203.204724
## listaCluster-hybrid_gaModel       150.45731  119.74910  181.165508
## gaModelCluster-hybrid_listaGA_New 249.92088  219.21268  280.629084
## listaCluster-hybrid_listaGA_New   227.88167  197.17346  258.589868
## listaCluster-gaModelCluster       -22.03922  -52.74742    8.668985
##                                      p adj
```

```
## lista-gaModel                     0.1697991
## hybrid_gaModel-gaModel            0.0000000
## hybrid_listaGA_New-gaModel        0.0000000
## gaModelCluster-gaModel            0.0000000
## listaCluster-gaModel              0.0000000
## hybrid_gaModel-lista              0.0002122
## hybrid_listaGA_New-lista          0.0000000
## gaModelCluster-lista              0.0000000
## listaCluster-lista                0.0000000
## hybrid_listaGA_New-hybrid_gaModel 0.0000000
## gaModelCluster-hybrid_gaModel     0.0000000
## listaCluster-hybrid_gaModel       0.0000000
## gaModelCluster-hybrid_listaGA_New 0.0000000
## listaCluster-hybrid_listaGA_New   0.0000000
## listaCluster-gaModelCluster       0.3163227
##
## $regions
##                          diff        lwr        upr p adj
## Kansai-Kanto       496.37177   473.7695   518.9740     0
## Tohoku-Kanto      1143.63742  1121.0352  1166.2397     0
## EastJapan-Kanto     91.40506    68.8028   114.0073     0
## Tohoku-Kansai      647.26565   624.6634   669.8679     0
## EastJapan-Kansai  -404.96671  -427.5690  -382.3645     0
## EastJapan-Tohoku -1052.23236 -1074.8346 -1029.6301     0
```

ANOVA - Specific analysis somente com Cluster.

Faço o ANOVA somente para os modelos "clusterizados"

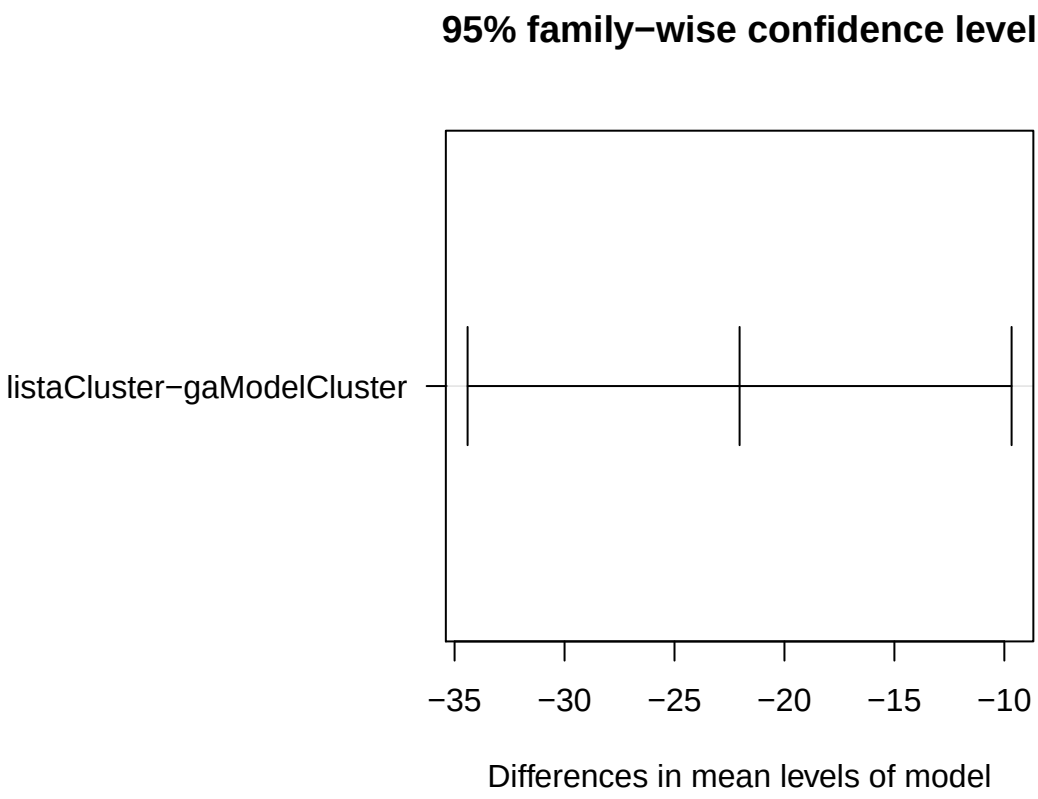
Primeiro crio o data frame somente com os modelos citados

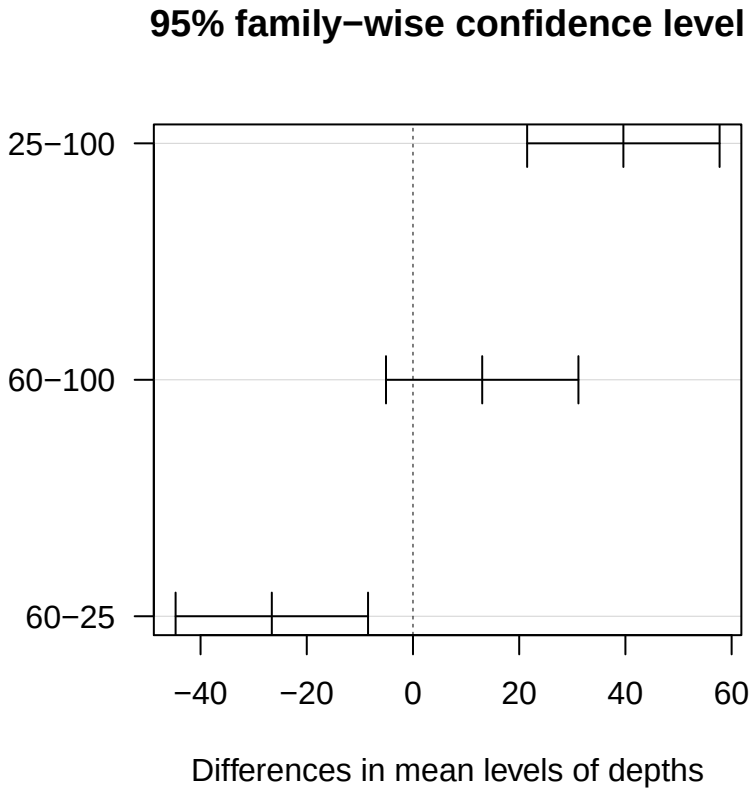
```
subTabela = finalData[finalData$model=='gaModelCluster'|finalData$model=='listaCluster',]
summary(subTabela)
```

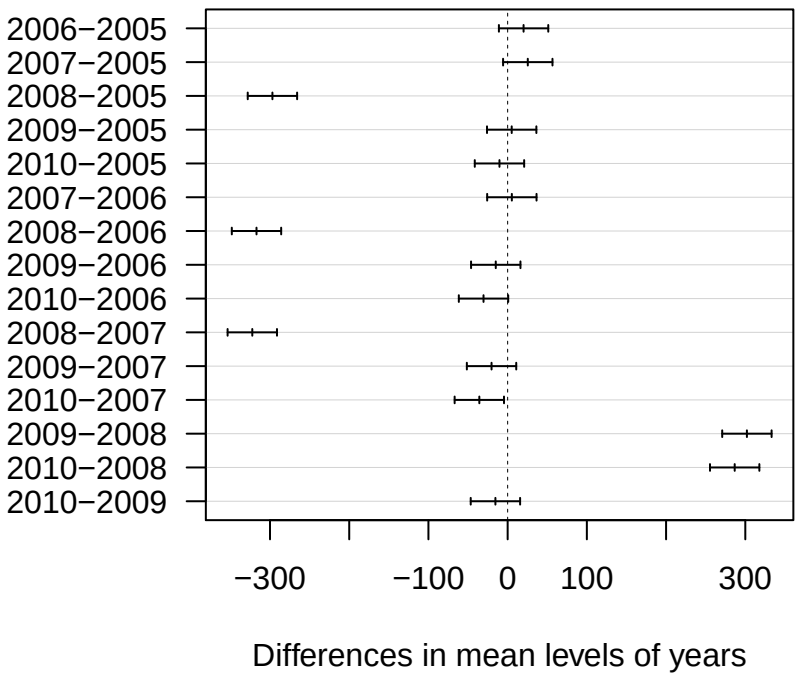
```
##  loglikeValues                  model     depths     years
##  Min.   :-2420   gaModel           :  0   100:480   2005:240
##  1st Qu.:-2032   lista             :  0   25 :480   2006:240
##  Median :-1634   hybrid_gaModel    :  0   60 :480   2007:240
##  Mean   :-1601   hybrid_listaGA_New:  0             2008:240
##  3rd Qu.:-1574   gaModelCluster    :720             2009:240
##  Max.   : -800   listaCluster      :720             2010:240
##       regions
##  Kanto    :360
##  Kansai   :360
##  Tohoku   :360
##  EastJapan:360
##
##
```

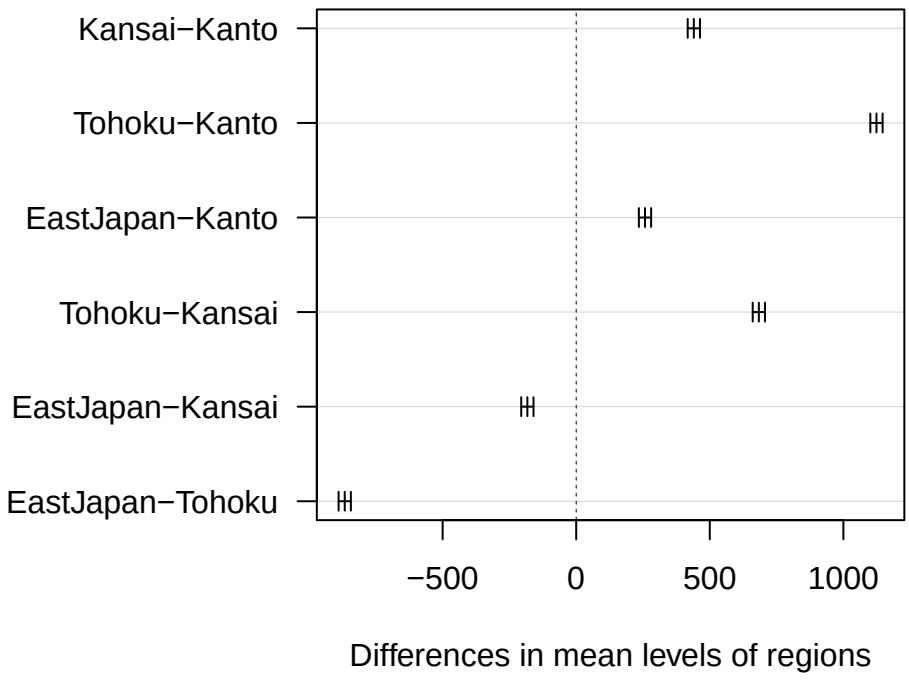
Aplico o anova, com a regressão para modelos, profundidades, anos e regiões.

```
resultANOVA = aov(loglikeValues~model+depths+years+regions , data = subTabela)
tuk = TukeyHSD(resultANOVA)
op <- par(mar = c(5,15,4,2) + 0.1)
plot(tuk,las=1)
```




95% family−wise confidence level
25−100
60−100
60−25
−40
−20
0
20
40
60
Differences in mean levels of depths


95% family−wise confidence level
2006−2005
2007−2005
2008−2005
2009−2005
2010−2005
2007−2006
2008−2006
2009−2006
2010−2006
2008−2007
2009−2007
2010−2007
2009−2008
2010−2008
2010−2009
−300
−100
0
100
300
Differences in mean levels of years




```r
print(tuk)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = loglikeValues ~ model + depths + years + regions, data = subTabela)
##
## $model
##                                  diff      lwr       upr     p adj
## listaCluster-gaModelCluster -22.03922 -34.4088 -9.669629 0.0004884
##
## $depths
##             diff        lwr       upr     p adj
## 25-100  39.61761  21.498345 57.736877 0.0000010
## 60-100  13.03637  -5.082893 31.155638 0.2101135
## 60-25  -26.58124 -44.700504 -8.461972 0.0017206
##
## $years
##                  diff         lwr          upr     p adj
## 2006-2005   20.120125  -11.046557   51.2868058 0.4388396
## 2007-2005   25.428493   -5.738188   56.5951741 0.1833601
## 2008-2005 -296.931458 -328.098139 -265.7647768 0.0000000
## 2009-2005    5.110504  -26.056177   36.2771851 0.9972103
## 2010-2005  -10.329327  -41.496008   20.8373539 0.9344671
## 2007-2006    5.308368  -25.858313   36.4750495 0.9966586
```

```
## 2008-2006 -317.051583 -348.218264 -285.8849014 0.0000000
## 2009-2006  -15.009621  -46.176302   16.1570605 0.7425591
## 2010-2006  -30.449452  -61.616133    0.7172293 0.0599571
## 2008-2007 -322.359951 -353.526632 -291.1932697 0.0000000
## 2009-2007  -20.317989  -51.484670   10.8486923 0.4273269
## 2010-2007  -35.757820  -66.924501   -4.5911390 0.0138287
## 2009-2008  302.041962  270.875281  333.2086431 0.0000000
## 2010-2008  286.602131  255.435450  317.7688119 0.0000000
## 2010-2009  -15.439831  -46.606512   15.7268500 0.7187745
##
## $regions
##                        diff       lwr       upr p adj
## Kansai-Kanto       440.2862  417.3493  463.2231     0
## Tohoku-Kanto      1123.9321 1100.9952 1146.8690     0
## EastJapan-Kanto    257.4748  234.5379  280.4117     0
## Tohoku-Kansai      683.6459  660.7090  706.5828     0
## EastJapan-Kansai -182.8114 -205.7483 -159.8745     0
## EastJapan-Tohoku -866.4573 -889.3942 -843.5204     0
```

Paired Design - Student t-test

Agora faço o Paired Design t.test aplicando para todas as combinações possíveis de modelos, em todas as regiões e profundidades, para todos os anos.

Baseado nos arquivos que explicam o Paired Desing, escrevi o código a seguir. Porém não entendi porque ao fazer desta forma pode ser considerado um teste pareado. Os slides comparam duas formas de realizar este tipo de teste. Uma delas tem *seta* um parametro da função com **True**, explicitando que é um teste pareado. Já para o outra forma, esse parametro fica com **False**.

```
summary(finalData)
```

```
##  loglikeValues                 model     depths      years
##  Min.   :-3158   gaModel           :720   100:1440   2005:720
##  1st Qu.:-2079   lista             :720   25 :1440   2006:720
##  Median :-1679   hybrid_gaModel    :720   60 :1440   2007:720
##  Mean   :-1702   hybrid_listaGA_New:720              2008:720
##  3rd Qu.:-1602   gaModelCluster    :720              2009:720
##  Max.   : -800   listaCluster      :720              2010:720
##       regions
##  Kanto    :1080
##  Kansai   :1080
##  Tohoku   :1080
##  EastJapan:1080
##
##
```

```
# Summarize the n=30 repeated measures on each Problem:Algorithm combination by their mean value
ttestPaired= function(region){
    subTabela = finalData[finalData$depths==25&finalData$regions==region,]
    aggfinaldata<-aggregate(loglikeValues~years:model, data=subTabela,FUN=mean)
    # Perform paired t-test
    cat('in', region, 'the t.test between the models gaModel and lista is: ')
    difTimes<-with(aggfinaldata,loglikeValues[1:6]-loglikeValues[7:12])
```

```
    print(t.test(difTimes))
    cat('in', region, 'the t.test between the models gaModel and hybrid_gaModel is: ')
    difTimes<-with(aggfinaldata,loglikeValues[1:6]-loglikeValues[13:18])
    print(t.test(difTimes))
    cat('in', region, 'the t.test between the models gaModel and hybrid_listaGA_New is: ')
    difTimes<-with(aggfinaldata,loglikeValues[1:6]-loglikeValues[19:24])
    print(t.test(difTimes))
    cat('in', region, 'the t.test between the models gaModel and gaModelCluster is: ')
    difTimes<-with(aggfinaldata,loglikeValues[1:6]-loglikeValues[25:30])
    print(t.test(difTimes))
    cat('in', region, 'the t.test between the models gaModel and listaCluster is: ')
    difTimes<-with(aggfinaldata,loglikeValues[1:6]-loglikeValues[31:36])
    print(t.test(difTimes))
}

    ttestPaired('Kansai')
```

```
## in Kansai the t.test between the models gaModel and lista is:
##  One Sample t-test
##
## data:  difTimes
## t = 10.637, df = 5, p-value = 0.000127
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  24.06675 39.40531
## sample estimates:
## mean of x
##  31.73603
##
## in Kansai the t.test between the models gaModel and hybrid_gaModel is:
##  One Sample t-test
##
## data:  difTimes
## t = 1.1955, df = 5, p-value = 0.2855
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -4.693085 12.852947
## sample estimates:
## mean of x
##  4.079931
##
## in Kansai the t.test between the models gaModel and hybrid_listaGA_New is:
##  One Sample t-test
##
## data:  difTimes
## t = 17.138, df = 5, p-value = 1.238e-05
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##   79.70227 107.83100
## sample estimates:
## mean of x
##  93.76664
##
```

```
## in Kansai the t.test between the models gaModel and gaModelCluster is:
##  One Sample t-test
##
## data:  difTimes
## t = -3.2157, df = 5, p-value = 0.02358
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -12.753743  -1.422024
## sample estimates:
## mean of x
## -7.087883
##
## in Kansai the t.test between the models gaModel and listaCluster is:
##  One Sample t-test
##
## data:  difTimes
## t = 4.7105, df = 5, p-value = 0.005287
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##   6.07558 20.67227
## sample estimates:
## mean of x
##  13.37392
```

```
    ttestPaired('Tohoku')
```

```
## in Tohoku the t.test between the models gaModel and lista is:
##  One Sample t-test
##
## data:  difTimes
## t = -1.622, df = 5, p-value = 0.1657
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -13.769220   3.115127
## sample estimates:
## mean of x
## -5.327047
##
## in Tohoku the t.test between the models gaModel and hybrid_gaModel is:
##  One Sample t-test
##
## data:  difTimes
## t = 6.624, df = 5, p-value = 0.001181
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  25.53039 57.91218
## sample estimates:
## mean of x
##  41.72128
##
## in Tohoku the t.test between the models gaModel and hybrid_listaGA_New is:
##  One Sample t-test
##
## data:  difTimes
```

```
## t = 3.3329, df = 5, p-value = 0.02071
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##   8.308453 64.338805
## sample estimates:
## mean of x
##  36.32363
##
## in Tohoku the t.test between the models gaModel and gaModelCluster is:
##  One Sample t-test
##
## data:  difTimes
## t = -9.4035, df = 5, p-value = 0.0002294
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -36.89030 -21.05111
## sample estimates:
## mean of x
## -28.97071
##
## in Tohoku the t.test between the models gaModel and listaCluster is:
##  One Sample t-test
##
## data:  difTimes
## t = -6.257, df = 5, p-value = 0.001529
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -33.37542 -13.93769
## sample estimates:
## mean of x
## -23.65656
```

```
    ttestPaired('EastJapan')
```

```
## in EastJapan the t.test between the models gaModel and lista is:
##  One Sample t-test
##
## data:  difTimes
## t = 1.9129, df = 5, p-value = 0.114
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -10.07453  68.68307
## sample estimates:
## mean of x
##  29.30427
##
## in EastJapan the t.test between the models gaModel and hybrid_gaModel is:
##  One Sample t-test
##
## data:  difTimes
## t = 6.5282, df = 5, p-value = 0.001262
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##   61.94934 142.42401
```

```
## sample estimates:
## mean of x
##  102.1867
##
## in EastJapan the t.test between the models gaModel and hybrid_listaGA_New is:
##  One Sample t-test
##
## data:  difTimes
## t = 11.564, df = 5, p-value = 8.482e-05
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  156.1337 245.3855
## sample estimates:
## mean of x
##  200.7596
##
## in EastJapan the t.test between the models gaModel and gaModelCluster is:
##  One Sample t-test
##
## data:  difTimes
## t = -8.8802, df = 5, p-value = 0.0003012
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -109.10009  -60.11634
## sample estimates:
## mean of x
## -84.60822
##
## in EastJapan the t.test between the models gaModel and listaCluster is:
##  One Sample t-test
##
## data:  difTimes
## t = -5.4451, df = 5, p-value = 0.002837
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -93.31209 -33.46295
## sample estimates:
## mean of x
## -63.38752
```

```
    ttestPaired('Kanto')
```

```
## in Kanto the t.test between the models gaModel and lista is:
##  One Sample t-test
##
## data:  difTimes
## t = 4.1215, df = 5, p-value = 0.00916
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##   4.985032 21.509870
## sample estimates:
## mean of x
##  13.24745
##
```

```
## in Kanto the t.test between the models gaModel and hybrid_gaModel is:
##  One Sample t-test
##
## data:  difTimes
## t = 1.3808, df = 5, p-value = 0.2259
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -1.542245  5.122177
## sample estimates:
## mean of x
##  1.789966
##
## in Kanto the t.test between the models gaModel and hybrid_listaGA_New is:
##  One Sample t-test
##
## data:  difTimes
## t = 5.8073, df = 5, p-value = 0.002136
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  23.43230 60.65227
## sample estimates:
## mean of x
##  42.04228
##
## in Kanto the t.test between the models gaModel and gaModelCluster is:
##  One Sample t-test
##
## data:  difTimes
## t = -3.3043, df = 5, p-value = 0.02137
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -9.408156 -1.175006
## sample estimates:
## mean of x
## -5.291581
##
## in Kanto the t.test between the models gaModel and listaCluster is:
##  One Sample t-test
##
## data:  difTimes
## t = 1.1659, df = 5, p-value = 0.2963
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  -3.474332  9.241409
## sample estimates:
## mean of x
##  2.883539
```

Conclusion

A one-way between subjects ANOVA was conducted to compare the effects of the models, the depths, the years and regions on the log-likelihood value. In this study there are 6 options for model: lista, gaModel, hybrid_gaModel, hybrid_list, gaModelCluster and listaCluster. Based on the results of the test, there was a

not a significant effect of the depths or years variables. For both cases at the we obtaind p>0.05 level for the depths condition [F(2) = 2.072, p = 0.126] and we also obtained p>0.05 for the years condition [F(5) = 0.050, p = 0.999]. There was a significant effect of the models condition (p>0.05 [F(5) = 9699.690, p<2e-16]) and regions condition (p>0.05 [F(3) = 764.220, p<2e-16]). Therefore, we conduct a new anova test, with only the last two variables to verify the influence of those conditions more accurately. The results only changed a little, maintaining the significant effect of both conditions, p>0.05 [F(5) = 9705.6, p<2e-16] and p>0.05 [F(3) = 764.7, p <2e-16], respectively.

Because we found statistically significant result, we applied a Post hoc comparisons using the Tukey HSD test. It compared each condition with all others. For example, it compares the values from the gaModel with the gaModelClustered. It indicated that the gaModelCluster and the listaCluster, when comparared with all other models, achieve greater log-likelihood values. Furthermore, we noticed that the depths conditions show a greater influence when the depth in smaller or equal to 25 km.

When comparing the models from the lista method and from the gaModel against themselves, with or without using clustering techniques, we found that there is no statistically significant result between the methods. That implies that it can be considered that the methods are obtain statistically equal results.

Therefore, based on the result of the HSD test, we performed a new AVOVA test, considering only the gaModelClustered and the listaClustered. That was meant not only to verify the previous results but also to certify if the depth influence is preserved.

Taken together, these results suggest that the using cluster and depth smaller or equal to 25km showed the best results.