Comparing Different Unit Test Generation Methods Through Different Mutation Operators

Installing and loading packages

```
install.packages("ggpubr")
```

```
## Installing package into '/home/beatriz/R/x86_64-pc-linux-gnu-library/3.4'
## (as 'lib' is unspecified)
```

```
install.packages("ggplot2")
```

```
## Installing package into '/home/beatriz/R/x86_64-pc-linux-gnu-library/3.4'
## (as 'lib' is unspecified)
```

```
install.packages("reshape")
```

```
## Installing package into '/home/beatriz/R/x86_64-pc-linux-gnu-library/3.4'
## (as 'lib' is unspecified)
```

```
install.packages("reshape2")
```

```
## Installing package into '/home/beatriz/R/x86_64-pc-linux-gnu-library/3.4'
## (as 'lib' is unspecified)
```

```
install.packages("dplyr")
```

```
## Installing package into '/home/beatriz/R/x86_64-pc-linux-gnu-library/3.4'
## (as 'lib' is unspecified)
```

```
library("ggplot2")
library("reshape")
library("reshape2")
```

```
##
## Attaching package: 'reshape2'
```

```
## The following objects are masked from 'package:reshape':
##
##     colsplit, melt, recast
```

```
library("ggpubr")
```

```
## Loading required package: magrittr
```

```
library("dplyr")
```

```
##
## Attaching package: 'dplyr'
```

```
## The following object is masked from 'package:reshape':
##
##     rename
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

Reading data

```
evoResults1 <- read.csv('/home/beatriz/Desktop/FinaldataSet/evoResultsEvoAvg.csv', se
p = ",", header = TRUE)
evoResults2 <- read.csv('/home/beatriz/Desktop/FinaldataSet/evoResults2EvoAvg.csv', s
ep = ",", header = TRUE)
evoResults3 <- read.csv('/home/beatriz/Desktop/FinaldataSet/evoResults3EvoAvg.csv', s
ep = ",", header = TRUE)

randoopResults1 <- read.csv('/home/beatriz/Desktop/FinaldataSet/randoopResultsRandoop
Avg.csv', sep = ",", header = TRUE)
randoopResults2 <- read.csv('/home/beatriz/Desktop/FinaldataSet/randoopResults2Randoo
pAvg.csv', sep = ",", header = TRUE)
randoopResults3 <- read.csv('/home/beatriz/Desktop/FinaldataSet/randoopResults3Randoo
pAvg.csv', sep = ",", header = TRUE)

manualResults1 <- read.csv('/home/beatriz/Desktop/FinaldataSet/manualSuitesResultsPIT
Avg.csv', sep = ",", header = TRUE)
manualResults2 <- read.csv('/home/beatriz/Desktop/FinaldataSet/manualSuitesResults2PI
TAvg.csv', sep = ",", header = TRUE)
manualResults3 <- read.csv('/home/beatriz/Desktop/FinaldataSet/manualSuitesResults3PI
TAvg.csv', sep = ",", header = TRUE)
```

Merging data

```
evoResults12 <- merge(evoResults1, evoResults2, all = TRUE)
#evo12
evoResults123 <- merge(evoResults12, evoResults3, all = TRUE)
evoResults123
```

```
##    MutationCoverage ReturnValsMutator ConditionalsBoundaryMutator
## 1         0.2342513         0.3130890                   0.1190476
## 2         0.2386252         0.3582857                   0.1266667
## 3         0.3170927         0.4830937                   0.3771800
## 4         0.3175885         0.3815475                   0.1591111
## 5         0.4180821         0.5737705                   0.3207164
## 6         0.4906863         0.5329545                   0.3189189
## 7         0.5098667         0.6414414                   0.3600000
## 8         0.5388335         0.6093407                   0.4948718
## 9         0.6936607         0.6723262                   0.6792952
## 10        0.7235751         0.8843750                   0.4694581
##    IncrementsMutator NegateConditionalsMutator MathMutator LineCoverage
## 1          0.3000000                 0.2519313  0.07142857    0.3844465
## 2          0.1000000                 0.2315603  0.16400000    0.3330896
## 3          0.2903226                 0.2956539  0.29569378    0.5184696
## 4          0.2000000                 0.3388959  0.25837500    0.4458619
## 5          0.3668317                 0.4334659  0.41811633    0.6117504
## 6          0.6909091                 0.5434978  0.49718310    0.6814879
## 7          0.9000000                 0.5099707  0.32592593    0.7715347
## 8          0.3411765                 0.5413497  0.57931034    0.6424541
## 9          0.7691824                 0.8096410  0.65455508    0.8792263
## 10         0.5200000                 0.7894340  0.68588957    0.9378749
##       Project Tool InvertNegsMutator VoidMethodCallMutator
## 1      e-mail  evo                NA            0.10769231
## 2         csv  evo                NA            0.07419355
## 3        bcel  evo                NA            0.22429358
## 4        lang  evo         0.6500000            0.31827309
## 5     imaging  evo         0.5833333            0.25390625
## 6  fileupload  evo                NA            0.27710843
## 7         cli  evo                NA            0.32051282
## 8   validator  evo                NA            0.16944444
## 9       codec  evo                NA            0.46905537
## 10 statistics  evo         0.6657143                    NA
```

```
randoopResults12 <- merge(randoopResults1, randoopResults2, all = TRUE)
#randoopResults12
randoopResults123 <- merge(randoopResults12, randoopResults3, all = TRUE)
#randoopResults123

manualResults12 <- merge(manualResults1, manualResults2, all = TRUE)
#manualResults12
manualResults123 <- merge(manualResults12, manualResults3, all = TRUE)
manualResults123
```

```
##    MutationCoverage ReturnValsMutator ConditionalsBoundaryMutator
## 1         0.3048661         0.3513514                   0.3432282
## 2         0.4836810         0.4124688                   0.4151261
## 3         0.6161790         0.5863874                   0.2857143
## 4         0.6388889         0.5852273                   0.4324324
## 5         0.7572283         0.7596154                   0.6153846
## 6         0.8267091         0.8974359                   0.5333333
## 7         0.8656351         0.8918300                   0.5274074
## 8         0.8672619         0.8302139                   0.6563877
## 9         0.8797280         0.8216146                   0.7187192
## 10        0.8986667         0.8468468                   0.6571429
##    IncrementsMutator NegateConditionalsMutator MathMutator LineCoverage
## 1          0.4946237                 0.3615172   0.3803828    0.4786764
## 2          0.7116705                 0.5370138   0.5001359    0.6528049
## 3          1.0000000                 0.7467811   0.7142857    0.8151876
## 4          0.6363636                 0.7982063   0.7464789    0.7638408
## 5          0.8529412                 0.8269939   0.8505747    0.7782152
## 6          0.7272727                 0.8936170   0.3673469    0.9180000
## 7          0.9535963                 0.9640440   0.8100000    0.9531415
## 8          0.9056604                 0.9353846   0.8781780    0.9208742
## 9          1.0000000                 0.9671698   0.9259202    0.9228792
## 10         1.0000000                 0.9618768   0.9259259    0.9669967
##       Project   Tool InvertNegsMutator VoidMethodCallMutator
## 1        bcel manual                NA             0.1904587
## 2     imaging manual         0.1666667             0.4241540
## 3      e-mail manual                NA             0.4358974
## 4  fileupload manual                NA             0.3253012
## 5   validator manual                NA             0.4166667
## 6         csv manual                NA             0.8225806
## 7        lang manual         0.9500000             0.8032129
## 8       codec manual                NA             0.8436482
## 9  statistics manual         0.9114286                    NA
## 10        cli manual                NA             0.8717949
```

```
evoAndRandoopDataSet <- merge(evoResults123, randoopResults123, all = TRUE)
completeDataSet <- merge(evoAndRandoopDataSet, manualResults123, all = TRUE)
#completeDataSet
```

Declaring common values

```
metrics1 = c("LineCoverage","MutationCoverage")
metrics2 = c("ReturnValsMutator","ConditionalsBoundaryMutator",
             "VoidMethodCallMutator","IncrementsMutator",
             "NegateConditionalsMutator","MathMutator", "InvertNegsMutator")

projects=c("BCEL","CLI","Codec", "CSV", "Email", "FileUpload", "Imaging", "Lang", "St
atistics", "Validator")
```

Melting data

```
completeDataSet.m1 <- melt(completeDataSet, id.var = "Tool", measure.vars = metrics1)
#completeDataSet.m1

completeDataSet.m2 <- melt(completeDataSet, id.var = "Tool", measure.vars = metrics2)
#completeDataSet.m2

completeDataSet.m3 <- melt(completeDataSet, id.vars = c("Tool", "Project"))
#completeDataSet.m3
```

Casting data

```
completeDataSet.c1 <- cast(completeDataSet.m3, Tool~variable+Project)
completeDataSet.c1
```

```
##      Tool MutationCoverage_bcel MutationCoverage_cli
## 1     evo             0.3170927            0.5098667
## 2 randoop             0.1407471            0.3025333
## 3  manual             0.3048661            0.8986667
##   MutationCoverage_codec MutationCoverage_csv MutationCoverage_e-mail
## 1              0.6936607            0.2386252               0.2342513
## 2              0.6430357            0.4646481               0.4535284
## 3              0.8672619            0.8267091               0.6161790
##   MutationCoverage_fileupload MutationCoverage_validator
## 1                   0.4906863                  0.5388335
## 2                   0.2506536                  0.4467597
## 3                   0.6388889                  0.7572283
##   MutationCoverage_imaging MutationCoverage_lang
## 1                0.4180821             0.3175885
## 2                0.1402246             0.3148940
## 3                0.4836810             0.8656351
##   MutationCoverage_statistics ReturnValsMutator_bcel ReturnValsMutator_cli
## 1                   0.7235751             0.4830937             0.6414414
## 2                   0.7407383             0.2441633             0.5387387
## 3                   0.8797280             0.3513514             0.8468468
##   ReturnValsMutator_codec ReturnValsMutator_csv ReturnValsMutator_e-mail
## 1               0.6723262             0.3582857                0.3130890
## 2               0.7030749             0.5828571                0.5732984
## 3               0.8302139             0.8974359                0.5863874
##   ReturnValsMutator_fileupload ReturnValsMutator_validator
## 1                    0.5329545                  0.6093407
## 2                    0.3659091                  0.5890110
## 3                    0.5852273                  0.7596154
##   ReturnValsMutator_imaging ReturnValsMutator_lang
## 1                 0.5737705             0.3815475
## 2                 0.2627561             0.3860130
## 3                 0.4124688             0.8918300
##   ReturnValsMutator_statistics ConditionalsBoundaryMutator_bcel
## 1                    0.8843750                         0.3771800
## 2                    0.8575521                         0.1150278
## 3                    0.8216146                         0.3432282
##   ConditionalsBoundaryMutator_cli ConditionalsBoundaryMutator_codec
## 1                       0.3600000                         0.6792952
## 2                       0.1114286                         0.4964758
## 3                       0.6571429                         0.6563877
##   ConditionalsBoundaryMutator_csv ConditionalsBoundaryMutator_e-mail
## 1                       0.1266667                          0.1190476
## 2                       0.2333333                          0.2333333
## 3                       0.5333333                          0.2857143
##   ConditionalsBoundaryMutator_fileupload
## 1                              0.3189189
## 2                              0.1432432
## 3                              0.4324324
##   ConditionalsBoundaryMutator_validator
## 1                             0.4948718
## 2                             0.3380342
## 3                             0.6153846
##   ConditionalsBoundaryMutator_imaging ConditionalsBoundaryMutator_lang
## 1                          0.32071636                         0.1591111
## 2                          0.06873185                         0.1879867
## 3                          0.41512605                         0.5274074
##   ConditionalsBoundaryMutator_statistics IncrementsMutator_bcel
```

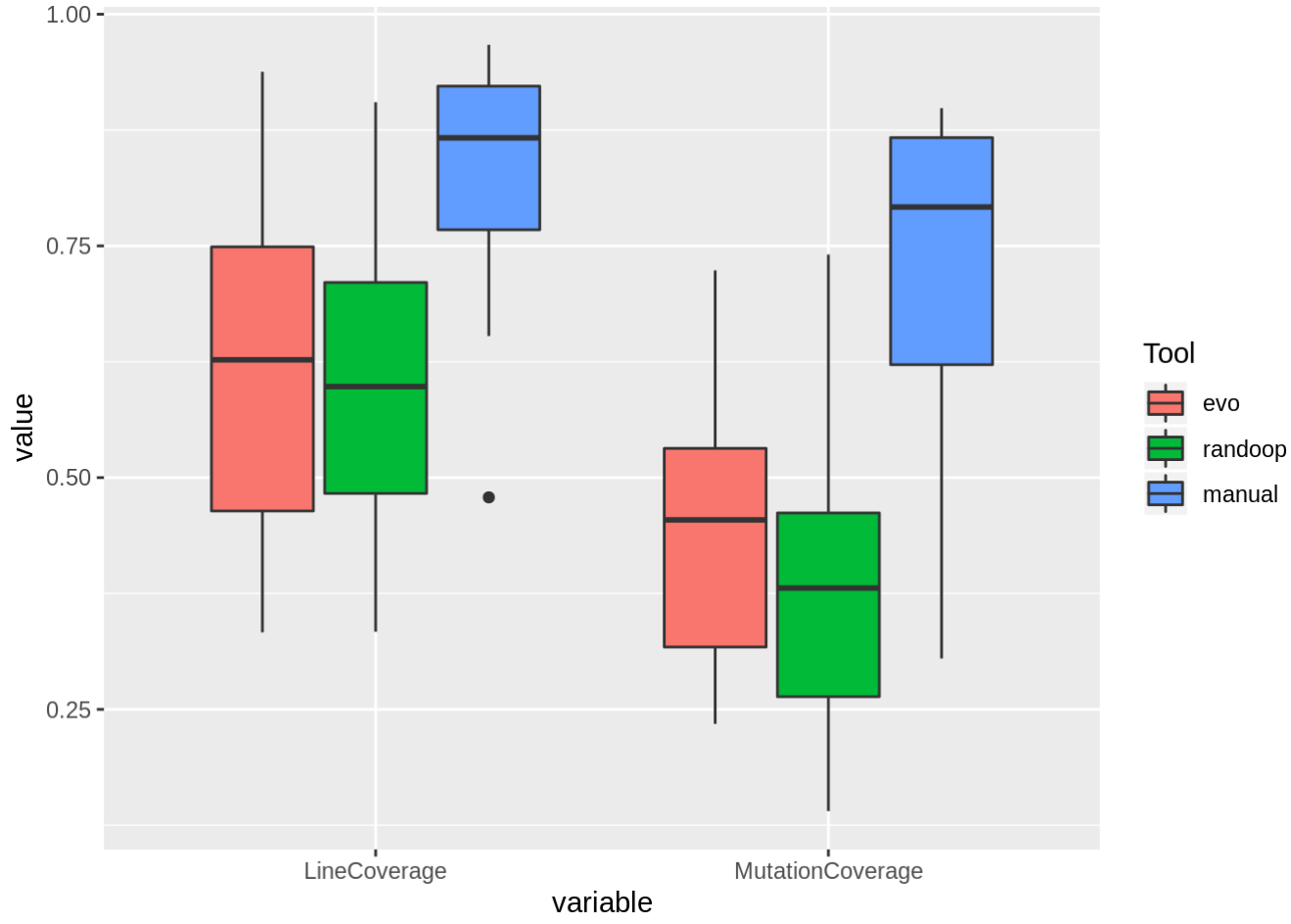
```
## 1                              0.4694581              0.2903226
## 2                              0.3197044              0.1591398
## 3                              0.7187192              0.4946237
##   IncrementsMutator_cli IncrementsMutator_codec IncrementsMutator_csv
## 1                0.9000               0.7691824             0.1000000
## 2                0.4125               0.5981132             0.3750000
## 3                1.0000               0.9056604             0.7272727
##   IncrementsMutator_e-mail IncrementsMutator_fileupload
## 1                     0.30                    0.6909091
## 2                     0.72                    0.1590909
## 3                     1.00                    0.6363636
##   IncrementsMutator_validator IncrementsMutator_imaging
## 1                   0.3411765                 0.3668317
## 2                   0.2911765                 0.1247525
## 3                   0.8529412                 0.7116705
##   IncrementsMutator_lang IncrementsMutator_statistics
## 1              0.2000000                         0.52
## 2              0.3703989                         0.70
## 3              0.9535963                         1.00
##   NegateConditionalsMutator_bcel NegateConditionalsMutator_cli
## 1                      0.2956539                    0.5099707
## 2                      0.1658633                    0.2504399
## 3                      0.3615172                    0.9618768
##   NegateConditionalsMutator_codec NegateConditionalsMutator_csv
## 1                       0.8096410                     0.2315603
## 2                       0.7218462                     0.5131206
## 3                       0.9353846                     0.8936170
##   NegateConditionalsMutator_e-mail NegateConditionalsMutator_fileupload
## 1                        0.2519313                             0.5434978
## 2                        0.5206009                             0.2677130
## 3                        0.7467811                             0.7982063
##   NegateConditionalsMutator_validator NegateConditionalsMutator_imaging
## 1                           0.5413497                           0.4334659
## 2                           0.4101840                           0.1556991
## 3                           0.8269939                           0.5370138
##   NegateConditionalsMutator_lang NegateConditionalsMutator_statistics
## 1                      0.3388959                            0.7894340
## 2                      0.3648787                            0.8641509
## 3                      0.9640440                            0.9671698
##   MathMutator_bcel MathMutator_cli MathMutator_codec MathMutator_csv
## 1        0.2956938       0.3259259         0.6545551       0.1640000
## 2        0.1167464       0.1259259         0.5826271       0.0980000
## 3        0.3803828       0.9259259         0.8781780       0.3673469
##   MathMutator_e-mail MathMutator_fileupload MathMutator_validator
## 1         0.07142857              0.4971831             0.5793103
## 2         0.32857143              0.2267606             0.3413793
## 3         0.71428571              0.7464789             0.8505747
##   MathMutator_imaging MathMutator_lang MathMutator_statistics
## 1           0.4181163        0.2583750              0.6858896
## 2           0.1175827        0.2149812              0.7492331
## 3           0.5001359        0.8100000              0.9259202
##   LineCoverage_bcel LineCoverage_cli LineCoverage_codec LineCoverage_csv
## 1         0.5184696        0.7715347          0.8792263        0.3330896
## 2         0.3889611        0.5235149          0.8550113        0.6917301
## 3         0.4786764        0.9669967          0.9208742        0.9180000
##   LineCoverage_e-mail LineCoverage_fileupload LineCoverage_validator
## 1           0.3844465               0.6814879              0.6424541
## 2           0.7168344               0.4693772              0.6429462
```

```
## 3           0.8151876               0.7638408              0.7782152
##   LineCoverage_imaging LineCoverage_lang LineCoverage_statistics
## 1            0.6117504         0.4458619               0.9378749
## 2            0.3336928         0.5535309               0.9050557
## 3            0.6528049         0.9531415               0.9228792
##   InvertNegsMutator_bcel InvertNegsMutator_cli InvertNegsMutator_codec
## 1                     NA                    NA                      NA
## 2                     NA                    NA                      NA
## 3                     NA                    NA                      NA
##   InvertNegsMutator_csv InvertNegsMutator_e-mail
## 1                    NA                       NA
## 2                    NA                       NA
## 3                    NA                       NA
##   InvertNegsMutator_fileupload InvertNegsMutator_validator
## 1                           NA                          NA
## 2                           NA                          NA
## 3                           NA                          NA
##   InvertNegsMutator_imaging InvertNegsMutator_lang
## 1                 0.5833333                   0.65
## 2                 0.1500000                   0.39
## 3                 0.1666667                   0.95
##   InvertNegsMutator_statistics VoidMethodCallMutator_bcel
## 1                    0.6657143                 0.22429358
## 2                    0.8142857                 0.05893578
## 3                    0.9114286                 0.19045872
##   VoidMethodCallMutator_cli VoidMethodCallMutator_codec
## 1                 0.3205128                   0.4690554
## 2                 0.0965812                   0.5638436
## 3                 0.8717949                   0.8436482
##   VoidMethodCallMutator_csv VoidMethodCallMutator_e-mail
## 1                0.07419355                   0.1076923
## 2                0.33548387                   0.1675214
## 3                0.82258065                   0.4358974
##   VoidMethodCallMutator_fileupload VoidMethodCallMutator_validator
## 1                      0.27710843                       0.1694444
## 2                      0.05301205                       0.1333333
## 3                      0.32530120                       0.4166667
##   VoidMethodCallMutator_imaging VoidMethodCallMutator_lang
## 1                    0.25390625                  0.3182731
## 2                    0.05426136                  0.1523728
## 3                    0.42415403                  0.8032129
##   VoidMethodCallMutator_statistics
## 1                               NA
## 2                               NA
## 3                               NA
```

Ploting Box-plots

Line Coverage and Mutation Coverage

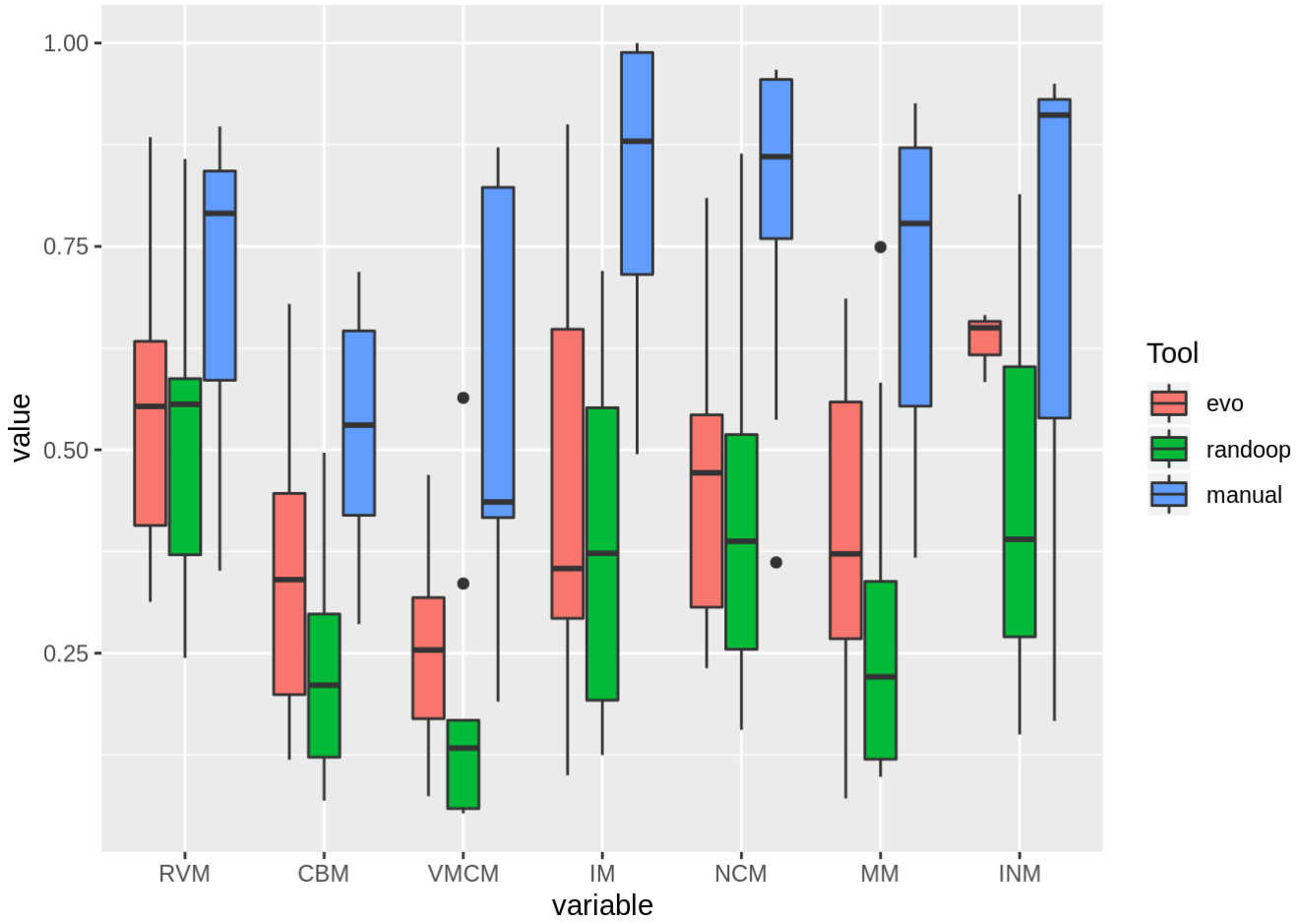
```
ggplot(data = completeDataSet.m1, aes(x=variable, y=value)) +
  geom_boxplot(aes(fill=Tool)) +
  scale_x_discrete(labels= c("LineCoverage", "MutationCoverage"))
```



PIT’s Default Mutation Operators

```
ggplot(data = completeDataSet.m2, aes(x=variable, y=value)) +
  geom_boxplot(aes(fill=Tool)) +
  scale_x_discrete(labels= c(
             "RVM","CBM",
             "VMCM","IM",
             "NCM","MM", "INM"))
```

```
## Warning: Removed 24 rows containing non-finite values (stat_boxplot).
```



Comparing Line Coverage per Tool

```
wilcox.test(evoResults123$LineCoverage, randoopResults123$LineCoverage, paired = TRUE
)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$LineCoverage and randoopResults123$LineCoverage
## V = 32, p-value = 0.6953
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(evoResults123$LineCoverage, manualResults123$LineCoverage, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$LineCoverage and manualResults123$LineCoverage
## V = 0, p-value = 0.001953
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(randoopResults123$LineCoverage, manualResults123$LineCoverage, paired = T
RUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  randoopResults123$LineCoverage and manualResults123$LineCoverage
## V = 0, p-value = 0.001953
## alternative hypothesis: true location shift is not equal to 0
```

Comparing Mutation Coverage per Tool

```
wilcox.test(evoResults123$MutationCoverage, randoopResults123$MutationCoverage, paire
d = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$MutationCoverage and randoopResults123$MutationCoverage
## V = 53, p-value = 0.005859
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(evoResults123$MutationCoverage, manualResults123$MutationCoverage, paired
= TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$MutationCoverage and manualResults123$MutationCoverage
## V = 0, p-value = 0.001953
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(randoopResults123$MutationCoverage, manualResults123$MutationCoverage, pa
ired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  randoopResults123$MutationCoverage and manualResults123$MutationCoverage
## V = 0, p-value = 0.001953
## alternative hypothesis: true location shift is not equal to 0
```

Comparing ReturnValsMutator Coverage per Tool

```
wilcox.test(evoResults123$ReturnValsMutator, randoopResults123$ReturnValsMutator, pai
red = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$ReturnValsMutator and randoopResults123$ReturnValsMutator
## V = 38, p-value = 0.3223
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(evoResults123$ReturnValsMutator, manualResults123$ReturnValsMutator, pair
ed = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$ReturnValsMutator and manualResults123$ReturnValsMutator
## V = 1, p-value = 0.003906
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(randoopResults123$ReturnValsMutator, manualResults123$ReturnValsMutator,
paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  randoopResults123$ReturnValsMutator and manualResults123$ReturnValsMutator
## V = 1, p-value = 0.003906
## alternative hypothesis: true location shift is not equal to 0
```

Comparing ConditionalsBoundaryMutator Coverage per Tool

```
wilcox.test(evoResults123$ConditionalsBoundaryMutator, randoopResults123$Conditionals
BoundaryMutator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$ConditionalsBoundaryMutator and randoopResults123$Conditional
sBoundaryMutator
## V = 53, p-value = 0.005859
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(evoResults123$ConditionalsBoundaryMutator, manualResults123$ConditionalsB
oundaryMutator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$ConditionalsBoundaryMutator and manualResults123$Conditionals
BoundaryMutator
## V = 2, p-value = 0.005859
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(randoopResults123$ConditionalsBoundaryMutator, manualResults123$Condition
alsBoundaryMutator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  randoopResults123$ConditionalsBoundaryMutator and manualResults123$Conditio
nalsBoundaryMutator
## V = 0, p-value = 0.001953
## alternative hypothesis: true location shift is not equal to 0
```

Comparing VoidMethodCallMutator Coverage per Tool

```
wilcox.test(evoResults123$VoidMethodCallMutator, randoopResults123$VoidMethodCallMuta
tor, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$VoidMethodCallMutator and randoopResults123$VoidMethodCallMut
ator
## V = 35, p-value = 0.1641
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(evoResults123$VoidMethodCallMutator, manualResults123$VoidMethodCallMutat
or, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$VoidMethodCallMutator and manualResults123$VoidMethodCallMuta
tor
## V = 0, p-value = 0.007813
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(randoopResults123$VoidMethodCallMutator, manualResults123$VoidMethodCallM
utator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  randoopResults123$VoidMethodCallMutator and manualResults123$VoidMethodCall
Mutator
## V = 0, p-value = 0.007813
## alternative hypothesis: true location shift is not equal to 0
```

Comparing IncrementsMutator Coverage per Tool

```
wilcox.test(evoResults123$IncrementsMutator, randoopResults123$IncrementsMutator, pai
red = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$IncrementsMutator and randoopResults123$IncrementsMutator
## V = 33, p-value = 0.625
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(evoResults123$IncrementsMutator, manualResults123$IncrementsMutator, pair
ed = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$IncrementsMutator and manualResults123$IncrementsMutator
## V = 0, p-value = 0.001953
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(randoopResults123$IncrementsMutator, manualResults123$IncrementsMutator,
paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  randoopResults123$IncrementsMutator and manualResults123$IncrementsMutator
## V = 0, p-value = 0.001953
## alternative hypothesis: true location shift is not equal to 0
```

Comparing NegateConditionalsMutator Coverage per Tool

```
wilcox.test(evoResults123$NegateConditionalsMutator, randoopResults123$NegateConditio
nalsMutator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$NegateConditionalsMutator and randoopResults123$NegateConditi
onalsMutator
## V = 48, p-value = 0.03711
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(evoResults123$NegateConditionalsMutator, manualResults123$NegateCondition
alsMutator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$NegateConditionalsMutator and manualResults123$NegateConditio
nalsMutator
## V = 0, p-value = 0.001953
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(randoopResults123$NegateConditionalsMutator, manualResults123$NegateCondi
tionalsMutator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  randoopResults123$NegateConditionalsMutator and manualResults123$NegateCond
itionalsMutator
## V = 0, p-value = 0.001953
## alternative hypothesis: true location shift is not equal to 0
```

Comparing MathMutator Coverage per Tool

```
wilcox.test(evoResults123$MathMutator, randoopResults123$MathMutator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$MathMutator and randoopResults123$MathMutator
## V = 48, p-value = 0.03711
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(evoResults123$MathMutator, manualResults123$MathMutator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123$MathMutator and manualResults123$MathMutator
## V = 1, p-value = 0.003906
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(randoopResults123$MathMutator, manualResults123$MathMutator, paired = TRU
E)
```

```
##
##  Wilcoxon signed rank test
##
## data:  randoopResults123$MathMutator and manualResults123$MathMutator
## V = 0, p-value = 0.001953
## alternative hypothesis: true location shift is not equal to 0
```

Comparing InvertNegsMutator Coverage per Tool

```
evoResults123WithoutNA <- evoResults123 %>% select(InvertNegsMutator) %>% filter(!is.
na(InvertNegsMutator))
#evoResults123WithoutNA
randoopResults123WithoutNA <- randoopResults123 %>% select(InvertNegsMutator) %>% fil
ter(!is.na(InvertNegsMutator))
#randoopResults123WithoutNA
manualResults123WithoutNA <- manualResults123 %>% select(InvertNegsMutator) %>% filte
r(!is.na(InvertNegsMutator))
#manualResults123WithoutNA

wilcox.test(evoResults123WithoutNA$InvertNegsMutator, randoopResults123WithoutNA$Inve
rtNegsMutator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123WithoutNA$InvertNegsMutator and randoopResults123WithoutNA$Inv
ertNegsMutator
## V = 5, p-value = 0.5
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(evoResults123WithoutNA$InvertNegsMutator, manualResults123WithoutNA$Inver
tNegsMutator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  evoResults123WithoutNA$InvertNegsMutator and manualResults123WithoutNA$Inve
rtNegsMutator
## V = 3, p-value = 1
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(randoopResults123WithoutNA$InvertNegsMutator, manualResults123WithoutNA$I
nvertNegsMutator, paired = TRUE)
```

```
##
##  Wilcoxon signed rank test
##
## data:  randoopResults123WithoutNA$InvertNegsMutator and manualResults123WithoutNA
$InvertNegsMutator
## V = 0, p-value = 0.25
## alternative hypothesis: true location shift is not equal to 0
```