

# MLEXPRESSO: differential expression and methylation analysis

Case study using RTCGA data

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## Contents

<b>1</b>	<b>Package (Abstract?)</b>	<b>1</b>
<b>2</b>	<b>Standard Workflow</b>	<b>1</b>
2.1	Methylation . . . . .	1
2.1.1	BRCA_methylation_chr17 data set . . . . .	1
2.1.2	Testing . . . . .	2
2.2	Expression . . . . .	3
2.2.1	BRCA_mRNAseq_chr17 data set . . . . .	3
2.2.2	Testing . . . . .	3
2.3	Comparing test results . . . . .	3
2.4	Choosing most different genes . . . . .	4
2.5	Visualization . . . . .	4

## 1 Package (Abstract?)

It is considered that the result of increased methylation is decreased gene expression. While, recent studies suggest that the relationship between methylation and expression is more complex than was previously thought. The package **MLEXPRESSO** provides methods to test for differential expression and methylation by use of the negative binomial distribution and t-test. Additionally **MLEXPRESSO** allows to visualize results in a simple way.

## 2 Standard Workflow

In this vignette we will work with the data sets containing information about gene expression and methylation for patients with breast cancer. We will analyze differences in methylation and expression for patients with different subtypes of BRCA cancer.

### 2.1 Methylation

#### 2.1.1 BRCA\_methylation\_chr17 data set

In this section, we will work with the methylation level data from TCGA database. Package contains **BRCA\_methylation\_chr17** dataset. **BRCA\_methylation\_chr17** contains information about methylation of CpG islands for patients with breast cancer. Rows of this data set correspond to patients, more precisely, to samples taken from patients. First column **SUBTYPE** corresponds to a subtype of BRCA cancer, next columns correspond to CpG islands. Values inside the table indicate the methylation level of CpG island for specified sample.

```
library(MLEXPRESSO)
```

```
library(MLEXPRESSodata)
```

```
head(BRCA_methylation_chr17)[1:5,1:4]
```

```
##                               SUBTYPE cg00021527 cg00031162 cg00032227
## TCGA-A1-A0SD-01A-11D-A112-05      LumA 0.03781858 0.7910348 0.006391233
## TCGA-A2-A04N-01A-11D-A112-05      LumA 0.01437552 0.7359370 0.008752293
## TCGA-A2-A04P-01A-31D-A032-05      Basal 0.01360124 0.6967802 0.009442039
## TCGA-A2-A04Q-01A-21D-A032-05      Basal 0.01525656 0.5341244 0.014674247
## TCGA-A2-A04T-01A-21D-A032-05      Basal 0.01167384 0.7378100 0.012251559
```

In this analysis we would like to find genes with different methylation and expression. At first we need to use function `aggregate_probes`, which generates new data frame with CpG islands mapped to genes.

```
BRCA_methylation_gen <- aggregate_probes(BRCA_methylation_chr17[, -1])
head(BRCA_methylation_gen)[1:5,1:4]
```

```
##                               AANAT    AARSD1    AATF    AATK
## TCGA-A1-A0SD-01A-11D-A112-05 0.7148533 0.8625816 0.24294092 0.7835302
## TCGA-A2-A04N-01A-11D-A112-05 0.5850106 0.8355825 0.21367129 0.8466190
## TCGA-A2-A04P-01A-31D-A032-05 0.4495537 0.8786166 0.03277413 0.3417919
## TCGA-A2-A04Q-01A-21D-A032-05 0.7120650 0.8819490 0.03460160 0.7264985
## TCGA-A2-A04T-01A-21D-A032-05 0.6010397 0.7739978 0.02501599 0.6276399
```

In this case we have two conditions, connected with subtypes of breast cancer.

Before we go to the testing, we need to define condition values for each sample. We would like to test for differences between LumA subtype and other subtypes of breast cancer, so we create a vector, which each element corresponds to a sample. Our division into this two groups relies on numbers of occurrences of each subtype. The LumA subtype is the most common, in case of breast cancer.

```
condition_met <- ifelse(BRCA_methylation_chr17$SUBTYPE=="LumA", "LumA", "other")
head(condition_met, 8)
```

```
## [1] "LumA" "LumA" "other" "other" "other" "other" "LumA" "other"
```

### 2.1.2 Testing

```
res_met <- calculate_test(BRCA_methylation_chr17[, -1], condition_met, test="ttest")
head(res_met)
```

```
##      id log2.fold      pval mean_LumA mean_other      mean
## 1 cg10275770 -0.1515132 3.795188e-17 0.2547275 0.4062407 0.3330801
## 2 cg06144905 0.1738623 9.908386e-14 0.5010717 0.3272094 0.4111616
## 3 cg04049033 -0.1027159 1.513031e-13 0.5931423 0.6958582 0.6462602
## 4 cg12045829 -0.1341285 5.910592e-12 0.1791401 0.3132686 0.2485025
## 5 cg02473123 0.0982269 1.653082e-11 0.8635077 0.7652808 0.8127112
## 6 cg05246522 0.1997340 2.069380e-11 0.658270 0.458536 0.5549808
```

## 2.2 Expression

### 2.2.1 BRCA\_mRNAseq\_chr17 data set

Data set `BRCA_mRNAseq_chr17` contains information about gene expression. This data set contains per-gene read counts computed for genes for 736 patients with breast cancer. Rows of this data set correspond to samples taken from patients. First column `SUBTYPE` corresponds to a subtype of BRCA cancer, next columns correspond to genes.

```
BRCA_mRNAseq_chr17[1:5,1:5]
```

```
##              SUBTYPE AANAT AARSD1 AATF AATK
## TCGA-A1-AOSB-01A-11R-A144-07 Normal    9  2354 2870  317
## TCGA-A1-AOSD-01A-11R-A115-07 LumA      2  1846 5656  312
## TCGA-A1-AOSE-01A-11R-A084-07 LumA     11  3391 9522  736
## TCGA-A1-AOSF-01A-11R-A144-07 LumA      0  2169 4625  169
## TCGA-A1-AOSG-01A-11R-A144-07 LumA      1  2273 3473   92
```

In our example we will test for differential expression between groups with LumA breast cancer subtype and other subtypes of that cancer. Again we will use vector `conditions`, which consist of two values corresponds to subtype of breast cancer: LumA and other.

```
condition_exp <- ifelse(BRCA_mRNAseq_chr17$SUBTYPE=="LumA", "LumA", "other")
head(condition_exp, 8)
```

```
## [1] "other" "LumA" "LumA" "LumA" "LumA" "LumA" "other" "LumA"
```

### 2.2.2 Testing

```
res_exp <- calculate_test(BRCA_mRNAseq_chr17[, -1], condition_exp, test="lrt")
head(res_exp)
```

```
##      id log2.fold      pval mean_LumA mean_other    mean
## 1  AURKB  2.339920 3.191000e-32  539.0426  2323.8868 1485.01
## 2   CBX2  2.895062 2.834335e-26  632.5106  4296.6038 2574.48
## 3  KPNA2  1.447288 8.551812e-24 11547.36   26427.38 19433.77
## 4  PRR11  3.822148 2.286874e-22   396.383   3479.981  2030.69
## 5  BIRC5  1.988998 1.953941e-21  1957.085   6658.358  4448.76
## 6   GSG2  1.405039 3.527773e-21   278.2128   629.3396   464.31
```

## 2.3 Comparing test results

```
genes_comparison <- calculate_comparison_table(BRCA_mRNAseq_chr17[, -1], BRCA_methylation_gen,
                                              condition_exp, condition_met, test1="nbinom2", test2="ttest")
```

```
## Warning: Column `id` joining character vector and factor, coercing into
## character vector
```

```
head(genes_comparison)
```

```
##      id nbinom2.log2.fold nbinom2.pval ttest.log2.fold  ttest.pval
## 59  AURKB           2.360714 1.704243e-37    0.0017389592 2.077252e-01
## 102 CBX2           2.905397 5.402147e-31    0.0584687549 1.214043e-06
## 327 KPNA2          1.466181 3.396674e-26    0.0012105971 7.505750e-01
```

```
## 277 GSG2          1.426569 3.325659e-25 -0.0018566938 2.411495e-01
## 66 BIRC5          2.004989 9.482155e-24 -0.0005444811 5.330216e-01
## 334 KRT16         4.333332 4.102956e-19  0.0486814033 1.606151e-05
##      geom.mean.rank No.probes
## 59      1.881527e-19         2
## 102     8.098418e-19         2
## 327     1.596702e-13         1
## 277     2.831926e-13         2
## 66      2.248153e-12         1
## 334     2.567093e-12         2
```

## 2.4 Choosing most different genes

Sorting ...

```
genes_comparison_sorted <- genes_comparison[order(genes_comparison$ttest.pval), ]
head(genes_comparison_sorted)
```

```
##      id nbinom2.log2.fold nbinom2.pval ttest.log2.fold  ttest.pval
## 302 ICAM2          0.2077055 2.102511e-01    -0.15151320 3.754116e-17
## 519 RILP           0.3139026 5.252448e-02    -0.05073691 2.575168e-13
## 466 PIPOX          0.3589979 4.371416e-02     0.11505558 5.360053e-12
## 652 TNFSF12       -0.4357410 3.486764e-04    -0.13412855 5.867083e-12
## 133 CD7            1.3728093 9.099866e-07     0.09822690 1.641919e-11
## 341 KSR1           0.4261993 1.658465e-02     0.19973400 2.054467e-11
##      geom.mean.rank No.probes
## 302 2.809461e-09         2
## 519 1.163011e-07         2
## 466 4.840560e-07         2
## 652 4.522956e-08         2
## 133 3.865391e-09         1
## 341 5.837174e-07         1
```

ICAM2!

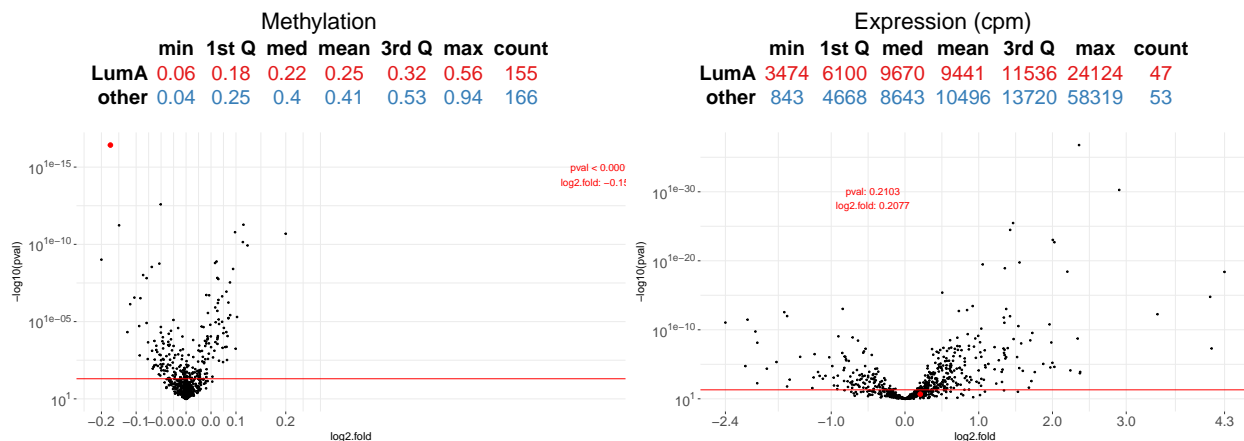
## 2.5 Visualization

Visualizing chosen gene - IGFALS.

```
test_exp <- genes_comparison[,c(1,2,3)]
test_met <- genes_comparison[,c(1,4,5)]

plot_volcano(BRCA_methylation_chr17[, -1], BRCA_mRNAseq_chr17[, -1], condition_met, condition_exp,
             "ICAM2",
             test_exp, test_met,
             values=TRUE)
```

## ICAM2



Note that `plot_gene` methylation require data frame with cpG islands, not genes.

```
plot_gene(BRCA_methylation_chr17, BRCA_mRNAseq_chr17, condition_met, condition_exp, "ICAM2")
```

## ICAM2

