# Homework #4

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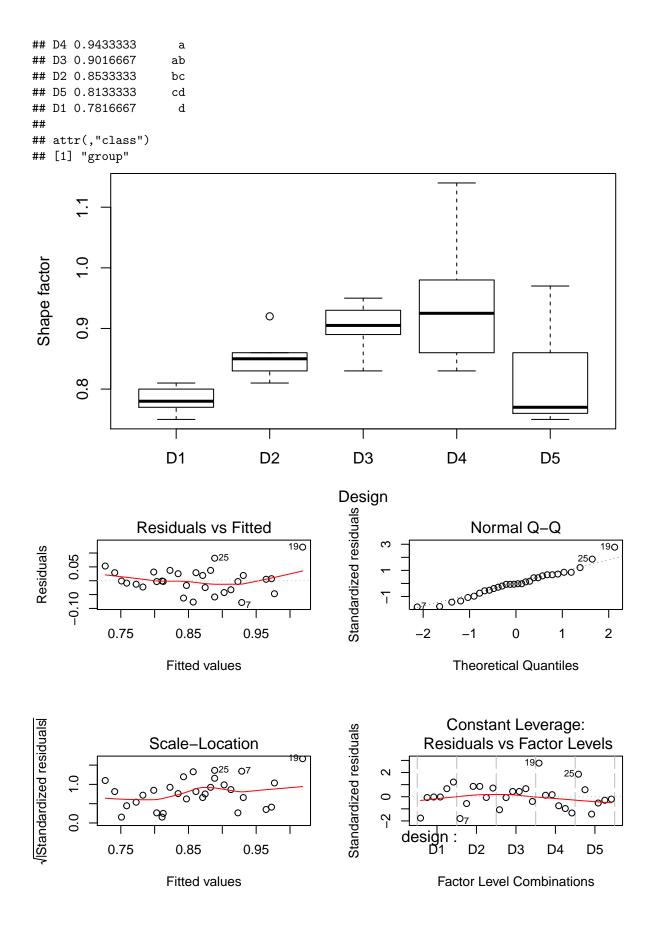
Question 1: Effect of 4 chemical agents on the strength of a particular type of cloth

```
Df Sum Sq Mean Sq F value
                                         Pr(>F)
## chem
               3 12.95
                          4.32 2.376
                                          0.121
               4 157.00
                          39.25 21.606 2.06e-05 ***
## Residuals
              12 21.80
                           1.82
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
## Call:
## aov(formula = ts ~ chem + bolt, data = dat)
##
## Residuals:
               1Q Median
##
      Min
                               ЗQ
                                      Max
## -1.3500 -0.7375 -0.3500 0.7000 1.8500
## Coefficients:
              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 72.3500
                          0.8524 84.873 < 2e-16 ***
## chemC2
                0.8000
                           0.8524
                                  0.938 0.366507
## chemC3
                           0.8524
                                   2.112 0.056374 .
                1.8000
## chemC4
                2.0000
                           0.8524
                                   2.346 0.036968 *
                           0.9531 -5.246 0.000206 ***
## boltB2
               -5.0000
## boltB3
               2.0000
                           0.9531 2.098 0.057699
               -0.7500
                           0.9531 -0.787 0.446584
## boltB4
                           0.9531 -5.246 0.000206 ***
## boltB5
               -5.0000
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
## Residual standard error: 1.348 on 12 degrees of freedom
## Multiple R-squared: 0.8863, Adjusted R-squared:
## F-statistic: 13.36 on 7 and 12 DF, p-value: 8.335e-05
##
## $statistics
     MSerror Df Mean
                           CV t.value
                                           LSD
    1.816667 12 71.75 1.87852 2.178813 1.857323
##
##
## $parameters
```

test p.ajusted name.t ntr alpha

```
Fisher-LSD none chem 4 0.05
##
##
## $means
##
                         LCL
                                 UCL Min Max Q25 Q50 Q75
               std r
       ts
## C1 70.6 3.049590 5 69.28667 71.91333 67 74 68 71
                                                     73
## C2 71.4 3.049590 5 70.08667 72.71333 67
                                         75
                                             70 72 73
## C3 72.4 4.393177 5 71.08667 73.71333 68 78 68 73 75
## C4 72.6 2.607681 5 71.28667 73.91333 69 75 71 73 75
##
## $comparison
## NULL
##
## $groups
##
      ts groups
## C4 72.6
## C3 72.4
              ab
## C2 71.4
              ab
## C1 70.6
## attr(,"class")
## [1] "group"
Question 2: potential differences between nozzle designs, with velocity
##
              Df Sum Sq Mean Sq F value Pr(>F)
## design
              4 0.10218 0.025545 8.916 0.000266 ***
              5 0.06287 0.012573
                                  4.389 0.007364 **
## jev
            20 0.05730 0.002865
## Residuals
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
```

```
##
## Call:
## aov(formula = sf ~ design + jev, data = dat)
## Residuals:
##
        Min
                    1Q
                          Median
                                        3Q
                                                 Max
## -0.078667 -0.024167 -0.001833 0.028083 0.121333
##
## Coefficients:
##
               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 0.85700
                           0.03090 27.732 < 2e-16 ***
                0.07167
                           0.03090
                                     2.319 0.031091 *
## designD2
## designD3
                0.12000
                           0.03090
                                     3.883 0.000925 ***
## designD4
                           0.03090
                0.16167
                                     5.231 4.05e-05 ***
## designD5
                0.03167
                           0.03090
                                     1.025 0.317736
## jev14.37
               -0.05400
                           0.03385
                                    -1.595 0.126360
## jev16.59
               -0.04600
                           0.03385
                                    -1.359 0.189329
## jev20.43
               -0.10600
                           0.03385
                                    -3.131 0.005259 **
               -0.11600
                           0.03385
                                    -3.427 0.002672 **
## jev23.46
## jev28.74
               -0.13000
                           0.03385
                                    -3.840 0.001022 **
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.05353 on 20 degrees of freedom
## Multiple R-squared: 0.7423, Adjusted R-squared: 0.6263
## F-statistic: 6.401 on 9 and 20 DF, p-value: 0.0002787
## $statistics
##
                                 CV t.value
                                                    LSD
      MSerror Df
                      Mean
##
     0.002865 20 0.8586667 6.233582 2.085963 0.06446268
##
## $parameters
##
           test p.ajusted name.t ntr alpha
     Fisher-LSD
                    none design
                                   5 0.05
##
## $means
##
                       std r
                                   LCL
                                             UCL Min Max
                                                               Q25
                                                                     Q50
             sf
## D1 0.7816667 0.02136976 6 0.7360847 0.8272487 0.75 0.81 0.7725 0.780
## D2 0.8533333 0.03723797 6 0.8077513 0.8989153 0.81 0.92 0.8350 0.850
## D3 0.9016667 0.04215052 6 0.8560847 0.9472487 0.83 0.95 0.8900 0.905
## D4 0.9433333 0.11360751 6 0.8977513 0.9889153 0.83 1.14 0.8650 0.925
## D5 0.8133333 0.08664102 6 0.7677513 0.8589153 0.75 0.97 0.7600 0.770
##
         075
## D1 0.7950
## D2 0.8575
## D3 0.9275
## D4 0.9775
## D5 0.8400
## $comparison
## NULL
##
## $groups
             sf groups
```

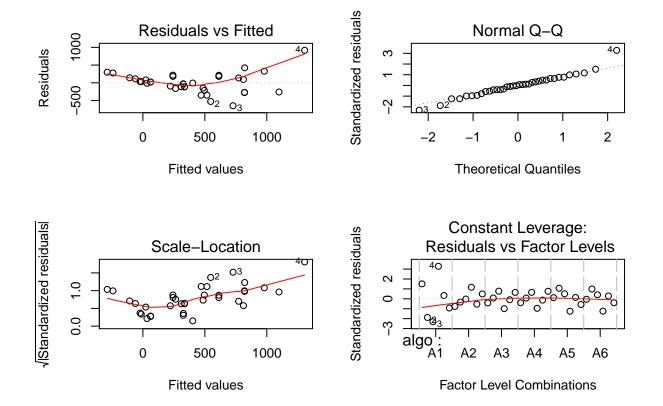


```
## [1] "c). Take velocity as the variable of secondary interest"
             Df Sum Sq Mean Sq F value Pr(>F)
## design
             4 0.1022 0.025545
                                5.314 0.00308 **
             25 0.1202 0.004807
## Residuals
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
## Call:
## aov(formula = sf ~ design, data = dat)
## Residuals:
       Min
                 1Q
                       Median
                                    3Q
## -0.113333 -0.040833 -0.003333 0.027917 0.196667
##
## Coefficients:
##
             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 0.78167 0.02830 27.617 < 2e-16 ***
## designD2
              0.07167
                        0.04003
                                1.790 0.085505 .
## designD3
              0.12000
                      0.04003
                                2.998 0.006068 **
## designD4
              ## designD5
           0.03167 0.04003 0.791 0.436317
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
## Residual standard error: 0.06933 on 25 degrees of freedom
## Multiple R-squared: 0.4596, Adjusted R-squared: 0.3731
## F-statistic: 5.314 on 4 and 25 DF, p-value: 0.003079
Question 3: Six algorithms were applied to several different software develop-
ment projects and the percent error in estimating the development cost was
observed
```

```
##
              Df Sum Sq Mean Sq F value Pr(>F)
## algo
               5 2850558 570112
                                   5.067 0.00242 **
               5 2223405 444681
                                   3.952 0.00888 **
## proj
              25 2812689
                         112508
## Residuals
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
##
## Call:
## aov(formula = cost ~ algo + proj, data = dat)
##
## Residuals:
##
               1Q Median
      Min
                               3Q
                                      Max
                     7.33 150.96
## -645.92 -152.71
                                  915.58
##
## Coefficients:
              Estimate Std. Error t value Pr(>|t|)
##
## (Intercept) 821.417
                          185.411
                                    4.430 0.000163 ***
                          193.656 -1.682 0.105083
## algoA2
              -325.667
## algoA3
              -485.500
                          193.656
                                   -2.507 0.019040 *
## algoA4
               -485.000
                          193.656
                                   -2.504 0.019151 *
              -834.833
                          193.656
                                   -4.311 0.000222 ***
## algoA5
## algoA6
              -788.500
                          193.656
                                   -4.072 0.000412 ***
## projP2
              -274.333
                          193.656
                                   -1.417 0.168940
## projP3
               -93.500
                          193.656
                                   -0.483 0.633428
                                    2.499 0.019374 *
## projP4
               484.000
                          193.656
## projP5
                -9.667
                          193.656
                                   -0.050 0.960585
               277.000
                                    1.430 0.164990
## projP6
                          193.656
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
## Residual standard error: 335.4 on 25 degrees of freedom
## Multiple R-squared: 0.6434, Adjusted R-squared: 0.5007
## F-statistic: 4.51 on 10 and 25 DF, p-value: 0.00107
## $statistics
##
                  Mean
                             CV t.value
     MSerror Df
     112507.5 25 398.75 84.11823 2.059539 398.8413
##
## $parameters
          test p.ajusted name.t ntr alpha
##
##
     Fisher-LSD
                           algo
                                  6 0.05
                    none
##
## $means
##
                      std r
                                 LCL
                                           UCL Min Max
                                                           Q25
                                                                 Q50
           cost
## A1 885.33333 813.33847 6 603.3099 1167.3567 21 2221 271.25 872.0 1159.25
## A2 559.66667 451.59480 6 277.6433
                                      841.6901 129 1306 294.75 366.0
## A3 399.83333 253.49747 6 117.8099
                                      681.8567
                                                84
                                                    794 240.00 379.0
## A4 400.33333 263.89367 6 118.3099
                                      682.3567
                                                83
                                                    826 241.50 358.0
                                                                      520.25
## A5 50.50000 48.60350 6 -231.5234
                                      332.5234
                                                11
                                                    121 16.00 26.5
## A6 96.83333 74.14962 6 -185.1901 378.8567
                                                20 199 39.50 78.5 153.50
##
```

```
## $comparison
## NULL
##
## $groups
##
            cost groups
## A1 885.33333
## A2 559.66667
                      ab
## A4 400.33333
                      bc
## A3 399.83333
                      bc
## A6
       96.83333
                       С
       50.50000
## A5
                       С
##
## attr(,"class")
## [1] "group"
      2000
Development Cost
      1500
      1000
      200
       0
                    A1
                                A2
                                             А3
                                                         Α4
                                                                      Α5
                                                                                  A6
                                               Algorithm
```

## [1] "Analyze the residuals"



Question 4: Road vs Brand for tire life

```
## [1] "Part 1"
               Df Sum Sq Mean Sq F value
                2 241.72 120.86
                                   40.66 7.15e-09 ***
## road
## brand
                2 155.39
                           77.69
                                   26.14 4.84e-07 ***
                4 195.61
                           48.90
                                   16.45 6.09e-07 ***
## road:brand
## Residuals
               27
                   80.25
                            2.97
##
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
##
## Call:
## lm(formula = tl ~ road + brand + road * brand, data = dat)
##
## Residuals:
##
     Min
              1Q Median
                            3Q
                                  Max
   -3.50 -1.25
                   0.25
                          1.25
                                 2.75
##
##
## Coefficients:
```

```
Estimate Std. Error t value Pr(>|t|)
## (Intercept)
                   38.000
                               0.862 44.083 < 2e-16 ***
                                       1.436 0.16262
## roadCon
                    1.750
                               1.219
## roadGra
                   -4.250
                               1.219 -3.486 0.00169 **
## brandY
                    2.750
                               1.219
                                       2.256 0.03239 *
## brandZ
                               1.219 -3.076 0.00476 **
                   -3.750
## roadCon:brandY
                   3.000
                               1.724
                                       1.740 0.09323 .
## roadGra:brandY
                   -4.250
                               1.724
                                     -2.465 0.02034 *
## roadCon:brandZ
                   -1.750
                               1.724 -1.015 0.31908
## roadGra:brandZ
                  4.750
                               1.724
                                       2.755 0.01037 *
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## Residual standard error: 1.724 on 27 degrees of freedom
## Multiple R-squared: 0.8808, Adjusted R-squared: 0.8454
## F-statistic: 24.93 on 8 and 27 DF, p-value: 1.479e-10
## [1] "Part 2"
##
              Df Sum Sq Mean Sq F value
                                          Pr(>F)
## road
               2 241.72 120.86
                                40.66 7.15e-09 ***
## brand
               2 155.39
                         77.69
                                 26.14 4.84e-07 ***
## road:brand
              4 195.61
                          48.90
                                  16.45 6.09e-07 ***
## Residuals
              27 80.25
                           2.97
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
##
## Call:
## lm(formula = tl ~ road + brand + road * brand, data = dat)
##
## Residuals:
     Min
             1Q Median
                           3Q
                                 Max
  -3.50 -1.25
##
                  0.25
                         1.25
                                2.75
## Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
##
## (Intercept)
                   45.500
                               0.862 52.784 < 2e-16 ***
## roadAsp
                   -4.750
                               1.219 -3.896 0.000582 ***
## roadGra
                  -13.250
                               1.219 -10.869 2.31e-11 ***
## brandX
                   -5.750
                               1.219 -4.717 6.52e-05 ***
## brandZ
                  -11.250
                               1.219 -9.228 7.72e-10 ***
## roadAsp:brandX
                               1.724
                                      1.740 0.093225 .
                    3.000
## roadGra:brandX
                    7.250
                               1.724
                                       4.205 0.000257 ***
## roadAsp:brandZ
                    4.750
                               1.724
                                       2.755 0.010375 *
## roadGra:brandZ
                   13.750
                               1.724
                                       7.976 1.43e-08 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.724 on 27 degrees of freedom
## Multiple R-squared: 0.8808, Adjusted R-squared: 0.8454
## F-statistic: 24.93 on 8 and 27 DF, p-value: 1.479e-10
## [1] "Part 3 "
##
              Df Sum Sq Mean Sq F value
                                          Pr(>F)
```

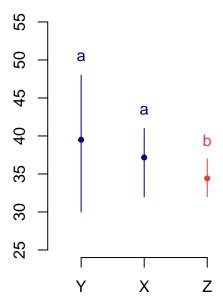
```
## road
               2 241.72 120.86
                                  40.66 7.15e-09 ***
## brand
                                  26.14 4.84e-07 ***
               2 155.39
                          77.69
## road:brand
                          48.90
                                  16.45 6.09e-07 ***
              4 195.61
## Residuals
              27 80.25
                           2.97
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
##
## lm(formula = tl ~ road + brand + road * brand, data = dat)
##
## Residuals:
##
     Min
             10 Median
                           3Q
                                 Max
##
  -3.50 -1.25
                  0.25
                         1.25
                                2.75
##
## Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)
                   34.750
                               0.862 40.313 < 2e-16 ***
## roadCon
                   -0.500
                               1.219 -0.410 0.68493
                               1.219 -0.410 0.68493
## roadAsp
                   -0.500
## brandY
                   -2.500
                               1.219 -2.051 0.05011 .
## brandX
                               1.219 -0.820 0.41923
                   -1.000
## roadCon:brandY
                   13.750
                               1.724
                                       7.976 1.43e-08 ***
## roadAsp:brandY
                    9.000
                               1.724
                                       5.220 1.69e-05 ***
## roadCon:brandX
                    6.500
                               1.724
                                       3.770 0.00081 ***
## roadAsp:brandX
                    4.750
                               1.724
                                       2.755 0.01037 *
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
## Residual standard error: 1.724 on 27 degrees of freedom
## Multiple R-squared: 0.8808, Adjusted R-squared: 0.8454
## F-statistic: 24.93 on 8 and 27 DF, p-value: 1.479e-10
## [1] "Part 4 "
##
## Call:
## lm(formula = tl ~ road + brand, data = dat)
## Residuals:
      Min
               1Q Median
                               30
## -6.0556 -1.8472 0.0278 1.4236 5.6944
##
## Coefficients:
##
              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 37.0278
                           0.4972 74.476 < 2e-16 ***
## road1
               -3.4444
                           0.7031 -4.899 2.87e-05 ***
## road2
                2.8056
                           0.7031
                                    3.990 0.000375 ***
## brand1
               -2.6111
                           0.7031 -3.714 0.000804 ***
## brand2
                2.4722
                           0.7031
                                    3.516 0.001373 **
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
## Residual standard error: 2.983 on 31 degrees of freedom
## Multiple R-squared: 0.5901, Adjusted R-squared: 0.5372
```

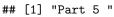
```
## F-statistic: 11.16 on 4 and 31 DF, p-value: 1.007e-05
## Full coefficients are
## (Intercept):
                    37.02778
## road:
                         Gra
                                    Con
                                                Asp
##
                   -3.444444 2.8055556 0.6388889
## brand:
                           7.
                                      Υ
##
                  -2.6111111 2.472222 0.1388889
##
## Call:
## lm(formula = tl ~ road + brand, data = dat)
## Residuals:
##
      Min
               1Q Median
                               3Q
                                      Max
## -6.0556 -1.8472 0.0278 1.4236 5.6944
##
## Coefficients:
              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 37.0278
                           0.4972 74.476 < 2e-16 ***
## road1
               -3.4444
                           0.7031 -4.899 2.87e-05 ***
## road2
                2.8056
                           0.7031
                                   3.990 0.000375 ***
## brand1
               -2.6111
                           0.7031 -3.714 0.000804 ***
## brand2
                2.4722
                           0.7031
                                    3.516 0.001373 **
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.05 '.' 0.1 ' ' 1
## Residual standard error: 2.983 on 31 degrees of freedom
## Multiple R-squared: 0.5901, Adjusted R-squared: 0.5372
## F-statistic: 11.16 on 4 and 31 DF, p-value: 1.007e-05
## $statistics
##
     MSerror Df
                               CV t.value
                                                LSD
                    Mean
     8.898746 31 37.02778 8.056321 2.039513 2.483793
##
## $parameters
##
          test p.ajusted name.t ntr alpha
##
    Fisher-LSD
                    none brand
                                  3 0.05
##
## $means
##
          tl
                   std r
                              LCL
                                       UCL Min Max
                                                     Q25 Q50
## X 37.16667 2.886751 12 35.41036 38.92297 32 41 34.75 38.0 39.25
## Y 39.50000 6.037760 12 37.74369 41.25631 30 48 34.00 41.0 42.75
## Z 34.41667 1.505042 12 32.66036 36.17297 32 37 33.00 34.5 35.25
##
## $comparison
## NULL
##
## $groups
##
          tl groups
## Y 39.50000
## X 37.16667
## Z 34.41667
##
```

```
## attr(,"class")
## [1] "group"
```

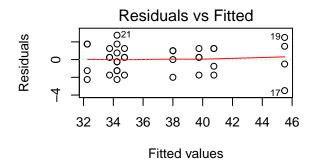
# **Groups and Range**

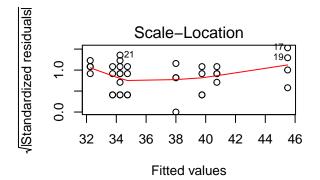
# **Groups and Range**

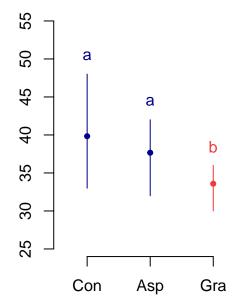


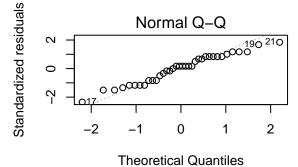


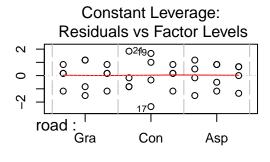
## [1] "Analyze the data"











**Factor Level Combinations** 

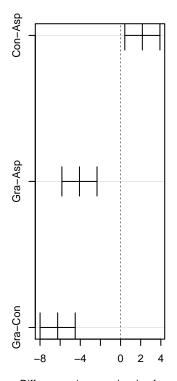
## [1] ""

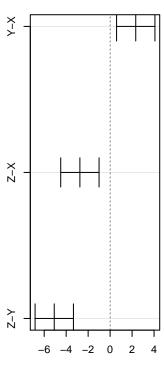
Standardized residuals

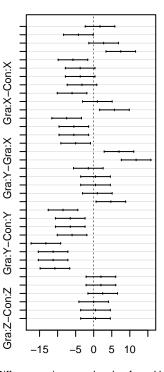
```
## [1] ""
## [1] ""
## [1] ""
## [1] "Effect of factors in pair"
## [1] "Reference Level 1"
##
     Tukey multiple comparisons of means
##
       95% family-wise confidence level
##
## Fit: aov(formula = tl ~ road + brand + road * brand, data = dat)
##
  $road
##
##
                diff
                            lwr
                                      upr
                                              p adj
## Con-Asp 2.166667 0.4215892 3.911744 0.0127310
## Gra-Asp -4.083333 -5.8284108 -2.338256 0.0000104
   Gra-Con -6.250000 -7.9950775 -4.504923 0.0000000
## $brand
##
            diff
                        lwr
                                  upr
                                          p adj
## Y-X 2.333333 0.5882559
                             4.078411 0.0071481
## Z-X -2.750000 -4.4950775 -1.004923 0.0015882
## Z-Y -5.083333 -6.8284108 -3.338256 0.0000003
##
## $`road:brand`
##
                 diff
                             lwr
                                       upr
                                               p adj
## Con:X-Asp:X
                 1.75
                       -2.351773 5.851773 0.8740057
                       -8.351773 -0.148227 0.0379881
## Gra:X-Asp:X
                -4.25
## Asp:Y-Asp:X
                 2.75
                       -1.351773 6.851773 0.4010522
                 7.50
                        3.398227 11.601773 0.0000443
## Con:Y-Asp:X
                -5.75
## Gra:Y-Asp:X
                      -9.851773 -1.648227 0.0018334
## Asp:Z-Asp:X
                -3.75
                      -7.851773 0.351773 0.0932295
## Con:Z-Asp:X
                -3.75
                       -7.851773 0.351773 0.0932295
                -3.25
                      -7.351773 0.851773 0.2069567
## Gra:Z-Asp:X
## Gra:X-Con:X
               -6.00 -10.101773 -1.898227 0.0010795
## Asp:Y-Con:X
                 1.00 -3.101773 5.101773 0.9951645
## Con:Y-Con:X
                 5.75
                        1.648227 9.851773 0.0018334
               -7.50 -11.601773 -3.398227 0.0000443
## Gra:Y-Con:X
## Asp:Z-Con:X
               -5.50
                      -9.601773 -1.398227 0.0031017
## Con:Z-Con:X
               -5.50
                      -9.601773 -1.398227 0.0031017
               -5.00
                      -9.101773 -0.898227 0.0087157
## Gra:Z-Con:X
## Asp:Y-Gra:X
                 7.00
                        2.898227 11.101773 0.0001279
## Con:Y-Gra:X
               11.75
                        7.648227 15.851773 0.0000000
## Gra:Y-Gra:X
                -1.50
                       -5.601773
                                 2.601773 0.9422170
## Asp:Z-Gra:X
                 0.50
                       -3.601773
                                 4.601773 0.9999688
## Con:Z-Gra:X
                 0.50
                       -3.601773
                                 4.601773 0.9999688
## Gra:Z-Gra:X
                 1.00
                      -3.101773 5.101773 0.9951645
                        0.648227 8.851773 0.0144195
## Con:Y-Asp:Y
                 4.75
## Gra:Y-Asp:Y
                -8.50 -12.601773 -4.398227 0.0000055
## Asp:Z-Asp:Y
                -6.50 -10.601773 -2.398227 0.0003718
## Con:Z-Asp:Y
               -6.50 -10.601773 -2.398227 0.0003718
## Gra:Z-Asp:Y -6.00 -10.101773 -1.898227 0.0010795
## Gra:Y-Con:Y -13.25 -17.351773 -9.148227 0.0000000
```

```
## Asp:Z-Con:Y -11.25 -15.351773 -7.148227 0.0000000
## Con:Z-Con:Y -11.25 -15.351773 -7.148227 0.0000000
## Gra:Z-Con:Y -10.75 -14.851773 -6.648227 0.0000001
## Asp:Z-Gra:Y
                2.00
                      -2.101773
                                 6.101773 0.7748122
## Con:Z-Gra:Y
                2.00
                      -2.101773
                                 6.101773 0.7748122
## Gra:Z-Gra:Y
                2.50
                      -1.601773 6.601773 0.5242729
## Con:Z-Asp:Z
                      -4.101773 4.101773 1.0000000
                0.00
                      -3.601773 4.601773 0.9999688
## Gra:Z-Asp:Z
                0.50
                0.50 -3.601773 4.601773 0.9999688
## Gra:Z-Con:Z
```

## 95% family-wise confidence lev 95% family-wise confidence lev 95% family-wise confidence lev







Differences in mean levels of road

##

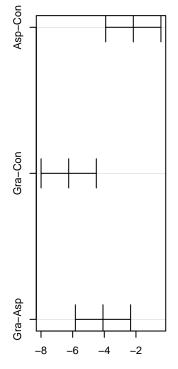
Differences in mean levels of brand

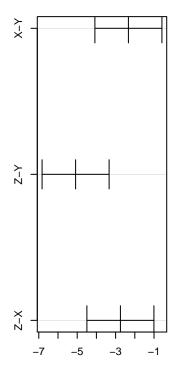
Differences in mean levels of road:brand

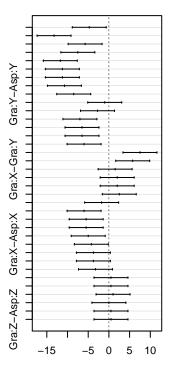
```
[1] "Reference Level 2"
##
     Tukey multiple comparisons of means
##
       95% family-wise confidence level
##
  Fit: aov(formula = tl ~ road + brand + road * brand, data = dat)
##
##
##
  $road
##
                diff
                           lwr
                                       upr
                                               p adj
## Asp-Con -2.166667 -3.911744 -0.4215892 0.0127310
## Gra-Con -6.250000 -7.995077 -4.5049225 0.0000000
## Gra-Asp -4.083333 -5.828411 -2.3382559 0.0000104
##
## $brand
##
            diff
                       lwr
                                   upr
                                           p adj
## X-Y -2.333333 -4.078411 -0.5882559 0.0071481
## Z-Y -5.083333 -6.828411 -3.3382559 0.0000003
## Z-X -2.750000 -4.495077 -1.0049225 0.0015882
```

```
## $`road:brand`
##
                diff
                            lwr
                                      upr
                                              p adj
## Asp:Y-Con:Y -4.75 -8.851773 -0.648227 0.0144195
## Gra:Y-Con:Y -13.25 -17.351773 -9.148227 0.0000000
## Con:X-Con:Y -5.75 -9.851773 -1.648227 0.0018334
## Asp:X-Con:Y -7.50 -11.601773 -3.398227 0.0000443
## Gra:X-Con:Y -11.75 -15.851773 -7.648227 0.0000000
## Con:Z-Con:Y -11.25 -15.351773 -7.148227 0.0000000
## Asp:Z-Con:Y -11.25 -15.351773 -7.148227 0.0000000
## Gra:Z-Con:Y -10.75 -14.851773 -6.648227 0.0000001
## Gra:Y-Asp:Y -8.50 -12.601773 -4.398227 0.0000055
## Con:X-Asp:Y -1.00 -5.101773 3.101773 0.9951645
## Asp:X-Asp:Y -2.75 -6.851773 1.351773 0.4010522
## Gra:X-Asp:Y -7.00 -11.101773 -2.898227 0.0001279
## Con:Z-Asp:Y -6.50 -10.601773 -2.398227 0.0003718
## Asp:Z-Asp:Y
               -6.50 -10.601773 -2.398227 0.0003718
## Gra:Z-Asp:Y -6.00 -10.101773 -1.898227 0.0010795
## Con:X-Gra:Y
                7.50
                      3.398227 11.601773 0.0000443
## Asp:X-Gra:Y
                      1.648227 9.851773 0.0018334
                5.75
## Gra:X-Gra:Y
                1.50
                     -2.601773 5.601773 0.9422170
## Con:Z-Gra:Y
                2.00
                     -2.101773 6.101773 0.7748122
## Asp:Z-Gra:Y
                2.00
                     -2.101773 6.101773 0.7748122
## Gra:Z-Gra:Y
                2.50 -1.601773 6.601773 0.5242729
## Asp:X-Con:X
              -1.75 -5.851773 2.351773 0.8740057
               -6.00 -10.101773 -1.898227 0.0010795
## Gra:X-Con:X
## Con:Z-Con:X
               -5.50 -9.601773 -1.398227 0.0031017
## Asp:Z-Con:X
               -5.50 -9.601773 -1.398227 0.0031017
## Gra:Z-Con:X
               -5.00 -9.101773 -0.898227 0.0087157
## Gra:X-Asp:X
               -4.25
                     -8.351773 -0.148227 0.0379881
## Con:Z-Asp:X
               -3.75 -7.851773 0.351773 0.0932295
## Asp:Z-Asp:X
               -3.75 -7.851773 0.351773 0.0932295
## Gra:Z-Asp:X
               -3.25
                     -7.351773 0.851773 0.2069567
## Con:Z-Gra:X
                0.50
                     -3.601773
                                4.601773 0.9999688
## Asp:Z-Gra:X
                0.50 -3.601773 4.601773 0.9999688
                      -3.101773 5.101773 0.9951645
## Gra:Z-Gra:X
                1.00
## Asp:Z-Con:Z
                0.00 -4.101773 4.101773 1.0000000
## Gra:Z-Con:Z
                0.50
                     -3.601773 4.601773 0.9999688
## Gra:Z-Asp:Z
                0.50 -3.601773 4.601773 0.9999688
```

### 95% family-wise confidence lev 95% family-wise confidence lev 95% family-wise confidence lev







Differences in mean levels of road

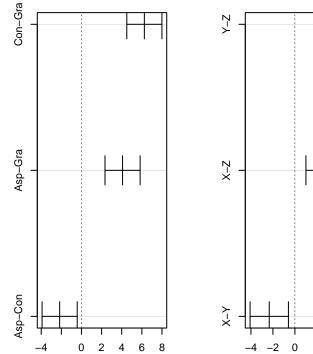
Differences in mean levels of brand

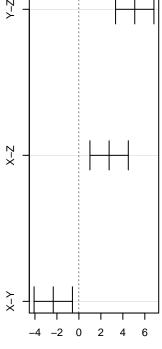
Differences in mean levels of road:brand

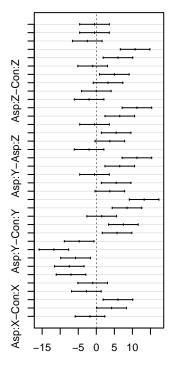
```
[1] "Reference Level 3"
##
     Tukey multiple comparisons of means
##
       95% family-wise confidence level
##
## Fit: aov(formula = tl ~ road + brand + road * brand, data = dat)
##
## $road
##
                diff
                           lwr
                                      upr
                                               p adj
           6.250000
                      4.504923
                                7.9950775 0.0000000
## Con-Gra
  Asp-Gra 4.083333
                      2.338256
                                5.8284108 0.0000104
  Asp-Con -2.166667 -3.911744 -0.4215892 0.0127310
##
##
## $brand
##
            diff
                       lwr
                                  upr
                                           p adj
## Y-Z 5.083333
                  3.338256
                            6.8284108 0.0000003
  X-Z 2.750000
                  1.004923
                            4.4950775 0.0015882
  X-Y -2.333333 -4.078411 -0.5882559 0.0071481
##
##
  $`road:brand`
##
                        diff
                                     lwr
                                               upr
## Con:Z-Gra:Z -5.000000e-01
                              -4.601773
                                         3.601773 0.9999688
## Asp:Z-Gra:Z -5.000000e-01
                              -4.601773
                                         3.601773 0.9999688
                                         1.601773 0.5242729
## Gra:Y-Gra:Z -2.500000e+00
                              -6.601773
## Con:Y-Gra:Z 1.075000e+01
                               6.648227 14.851773 0.0000001
## Asp:Y-Gra:Z 6.000000e+00
                               1.898227 10.101773 0.0010795
## Gra:X-Gra:Z -1.000000e+00
                              -5.101773
                                         3.101773 0.9951645
## Con:X-Gra:Z 5.000000e+00
                               0.898227 9.101773 0.0087157
```

```
## Asp:X-Gra:Z 3.250000e+00 -0.851773 7.351773 0.2069567
## Asp:Z-Con:Z -7.105427e-15 -4.101773 4.101773 1.0000000
## Gra:Y-Con:Z -2.000000e+00 -6.101773 2.101773 0.7748122
## Con:Y-Con:Z 1.125000e+01
                            7.148227 15.351773 0.0000000
## Asp:Y-Con:Z 6.500000e+00
                            2.398227 10.601773 0.0003718
## Gra:X-Con:Z -5.000000e-01 -4.601773 3.601773 0.9999688
## Con:X-Con:Z 5.500000e+00
                            1.398227 9.601773 0.0031017
## Asp:X-Con:Z 3.750000e+00 -0.351773 7.851773 0.0932295
## Gra:Y-Asp:Z -2.000000e+00 -6.101773 2.101773 0.7748122
## Con:Y-Asp:Z 1.125000e+01
                            7.148227 15.351773 0.0000000
## Asp:Y-Asp:Z 6.500000e+00
                            2.398227 10.601773 0.0003718
## Gra:X-Asp:Z -5.000000e-01 -4.601773 3.601773 0.9999688
## Con:X-Asp:Z 5.500000e+00
                             1.398227 9.601773 0.0031017
## Asp:X-Asp:Z 3.750000e+00 -0.351773 7.851773 0.0932295
## Con:Y-Gra:Y 1.325000e+01
                             9.148227 17.351773 0.0000000
## Asp:Y-Gra:Y 8.500000e+00
                            4.398227 12.601773 0.0000055
## Gra:X-Gra:Y 1.500000e+00 -2.601773 5.601773 0.9422170
## Con:X-Gra:Y 7.500000e+00
                             3.398227 11.601773 0.0000443
## Asp:X-Gra:Y 5.750000e+00
                             1.648227 9.851773 0.0018334
## Asp:Y-Con:Y -4.750000e+00 -8.851773 -0.648227 0.0144195
## Gra:X-Con:Y -1.175000e+01 -15.851773 -7.648227 0.0000000
## Con:X-Con:Y -5.750000e+00 -9.851773 -1.648227 0.0018334
## Asp:X-Con:Y -7.500000e+00 -11.601773 -3.398227 0.0000443
## Gra:X-Asp:Y -7.000000e+00 -11.101773 -2.898227 0.0001279
## Con:X-Asp:Y -1.000000e+00 -5.101773 3.101773 0.9951645
## Asp:X-Asp:Y -2.750000e+00 -6.851773 1.351773 0.4010522
## Con:X-Gra:X 6.000000e+00
                            1.898227 10.101773 0.0010795
## Asp:X-Gra:X 4.250000e+00
                             0.148227 8.351773 0.0379881
## Asp:X-Con:X -1.750000e+00 -5.851773 2.351773 0.8740057
```

# 95% family-wise confidence lev 95% family-wise confidence lev 95% family-wise confidence lev







Differences in mean levels of road

Differences in mean levels of brand

Differences in mean levels of road:brand

#### CODE

## Q1

```
#Set location
fil nam="HW4.3.txt"
df = file(fil_nam, open = "r") #open file
dat=NULL
k=1 #index of dat set
f1=c('B1','B2','B3','B4','B5')
f2=c('C1','C2','C3','C4')
rows=1
#Read each line of the data file
while (length(oneLine <- readLines(df, n = 1, warn = FALSE)) > 0) {
  num_lis = (strsplit(oneLine, " ")) #List of values in 1 line
  num_lis = as.numeric(num_lis[[1]]) # Convert them to numeric
  #Category the imported data
  interval=length(num_lis)
  for (i in 1:interval){
    dat$bolt[k]=f1[i]
    dat$chem[k]=f2[rows]
    dat$ts[k]=num_lis[i]
   k=k+1
  }
 rows=rows+1
close(df)
dat=data.frame(dat)
#############
fit=aov(ts~chem+bolt,data=dat)
summary(fit)
summary.lm(fit)
print(LSD.test(fit,'chem'))
```

#### $\mathbf{Q2}$

```
fil_nam="HW4.10.txt"
df = file(fil_nam, open = "r") #open file
dat=NULL
k=1 #index of dat set
velo=c('11.73', '14.37', '16.59', '20.43', '23.46', '28.74')
desi=c('D1','D2','D3','D4','D5')
rows=1
#Read each line of the data file
while (length(oneLine <- readLines(df, n = 1, warn = FALSE)) > 0) {
   num_lis = (strsplit(oneLine, " ")) #List of values in 1 line
   num_lis = as.numeric(num_lis[[1]]) # Convert them to numeric
   #Category the imported data
   interval=length(num_lis)
   for (i in 1:interval){
```

```
dat$jev[k]=velo[i]
   dat$design[k]=desi[rows]
   dat$sf[k]=num_lis[i]
   k=k+1
 }
 rows=rows+1
}
close(df)
dat=data.frame(dat)
###########
                     ##########
fit=aov(sf~design+jev,data=dat)
summary(fit)
summary.lm(fit)
print(LSD.test(fit, 'design'))
plot(dat$sf~dat$design,xlab='Design',ylab = 'Shape factor',title='Nozzle design vs Shape factor')
par(mfrow=c(2,2))
plot(fit)
print('c). Take velocity as the variable of secondary interest')
fit2=aov(sf~design,data=dat)
summary(fit2)
summary.lm(fit2)
```

# $\mathbf{Q3}$

```
fil nam="HW4.11.txt"
df = file(fil_nam, open = "r") #open file
dat=NULL
k=1 #index of dat set
coln=c('P1','P2','P3','P4','P5','P6')
rown=c('A1','A2','A3','A4','A5','A6')
rows=1
#Read each line of the data file
while (length(oneLine <- readLines(df, n = 1, warn = FALSE)) > 0) {
  num_lis = (strsplit(oneLine, " ")) #List of values in 1 line
 num_lis = as.numeric(num_lis[[1]]) # Convert them to numeric
  #Category the imported data
  interval=length(num_lis)
  for (i in 1:interval){
   dat$proj[k]=coln[i]
   dat$algo[k]=rown[rows]
   dat$cost[k]=num_lis[i]
   k=k+1
 }
 rows=rows+1
}
close(df)
dat=data.frame(dat)
############
                a
                     ###########
fit=aov(cost~algo+proj,data=dat)
summary(fit)
summary.lm(fit)
print(LSD.test(fit, 'algo'))
```

```
plot(dat$cost~dat$algo,xlab='Algorithm',ylab = 'Development Cost',title='Algorithm types vs Software De
print('Analyze the residuals')
par(mfrow=c(2,2))
plot(fit)
```

## $\mathbf{Q4}$

```
fil nam="HW4.4.txt"
df = file(fil_nam, open = "r") #open file
dat=NULL
k=1 #index of dat set
coln=c('X','Y','Z')
rown=c('Asp','Con','Gra')
rows=1
#Read each line of the data file
while (length(oneLine <- readLines(df, n = 1, warn = FALSE)) > 0) {
 num_lis = (strsplit(oneLine, ", ")) #List of values in 1 line
 num_lis = as.numeric(num_lis[[1]]) # Convert them to numeric
  #Category the imported data
  interval=length(num_lis)
  i=1
  while (i<=interval){</pre>
    dat\$brand[k] = coln[(i-1)%/%4+1]
    dat$road[k]=rown[rows]
    dat$tl[k]=num_lis[i]
    i=i+1
    k=k+1
 }
 rows=rows+1
}
close(df)
dat=data.frame(dat)
#####################
print('Part 1')
options(contrasts = c("contr.treatment", "contr.poly"))
fit1=lm(tl~road+brand+road*brand,data=dat)
fit1.aov=aov(tl~road+brand+road*brand,data=dat)
summary(fit1.aov)
summary(fit1)
#relevel the data to 2
print('Part 2')
1=2
dat = within(dat, brand <- relevel(brand, ref = 1))</pre>
dat = within(dat, road <- relevel(road, ref = 1))</pre>
fit2=lm(tl~road+brand+road*brand,data=dat)
fit2.aov=aov(tl~road+brand+road*brand,data=dat)
summary(fit2.aov)
summary(fit2)
#relever the data to 3
print('Part 3 ')
1=3
dat = within(dat, brand <- relevel(brand, ref = 1))</pre>
```

```
dat = within(dat, road <- relevel(road, ref = 1))</pre>
fit3=lm(tl~road+brand+road*brand,data=dat)
fit3.aov=aov(tl~road+brand+road*brand,data=dat)
summary(fit3.aov)
summary(fit3)
print('Part 4 ')
#Centralization side condition for data
options(contrasts = c("contr.sum", "contr.poly"))
1=1
dat = within(dat, brand <- relevel(brand, ref = 1))</pre>
dat = within(dat, road <- relevel(road, ref = 1))</pre>
fit4=lm(tl~road+brand,data=dat)
summary(fit4)
dummy.coef(fit4)
summary.lm(fit4)
par(mfrow=c(1,2))
fit4.lsd.b=LSD.test(fit4, 'brand')
print(fit4.lsd.b)
plot(fit4.lsd.b)
fit4.lsd.r=LSD.test(fit4,'road')
plot(fit4.lsd.r)
print('Part 5 ')
print('Analyze the data')
fit=aov(tl~road+brand+road*brand,data=dat)
par(mfrow=c(2,2))
plot(fit)
print('')
print('')
print('')
print('')
#Compare the effects of factors
print('Effect of factors in pair')
options(contrasts = c("contr.treatment", "contr.poly"))
print('Reference Level 1')
fit1.tukey=TukeyHSD(fit1.aov)
print(fit1.tukey)
par(mfrow=c(1,3))
plot(fit1.tukey)
print('Reference Level 2')
fit2.tukey=TukeyHSD(fit2.aov)
print(fit2.tukey)
par(mfrow=c(1,3))
plot(fit2.tukey)
print('Reference Level 3')
fit3.tukey=TukeyHSD(fit3.aov)
print(fit3.tukey)
par(mfrow=c(1,3))
plot(fit3.tukey)
```