Analysis and Results

2022-11-18

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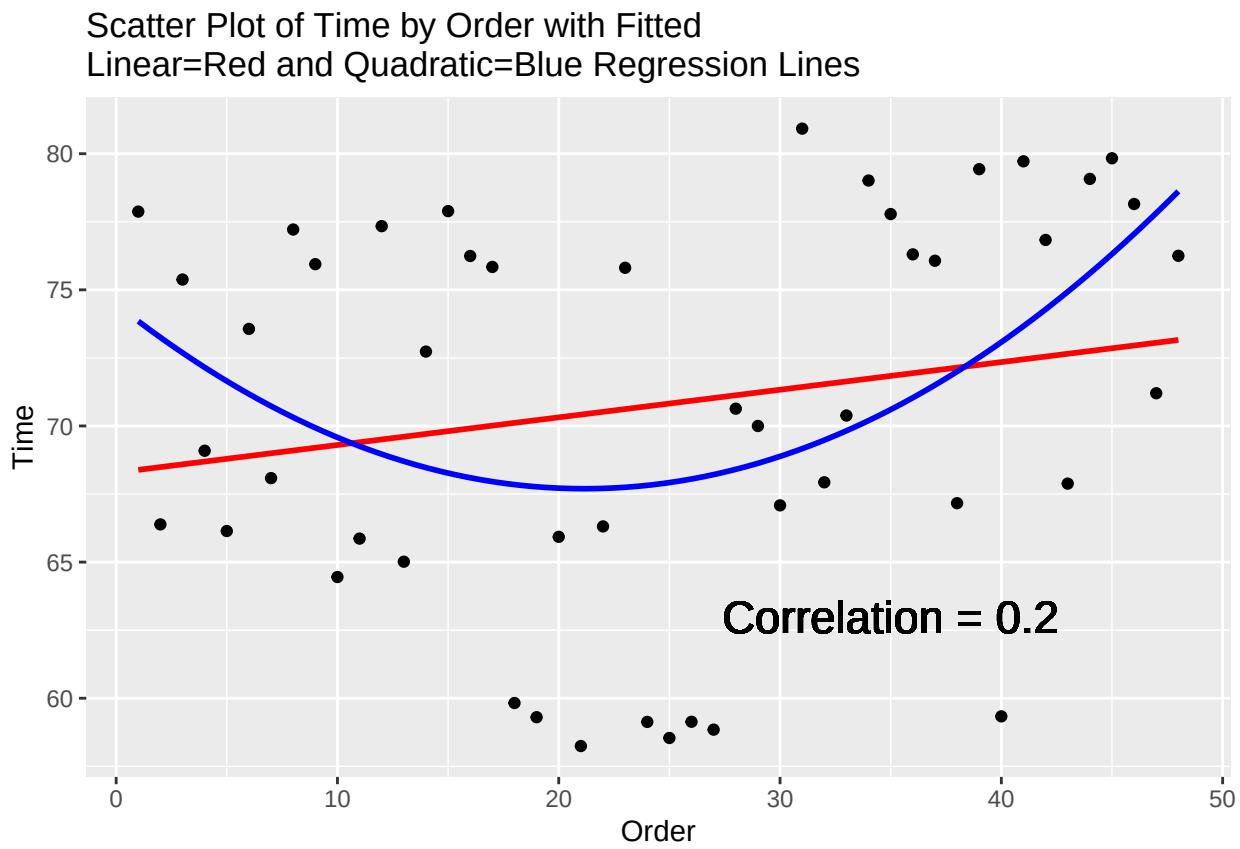
Order as a Model Covariate

We next consider the run order variable Order as a covariate. We first considered the relationship between Order and the response Time.

```
#using Halid's read_csv code to keep data frame consistent
library(tidyverse)
df_eff <- read_csv('effervescence.csv', col_types = 'fffnnn')


##get correlation to add to plot
correlation <- cor(df_eff$Time,df_eff$Order)

##construct scatter plot of Time by Order with fitted SLR line
## add correlation result to this plot
gOrderTime <- ggplot(df_eff,aes(x=Order,y=Time))
gOrderTime + geom_point() +geom_smooth(method=lm,col="Red",se = F) +
  geom_text(x=35,y=63,size=6, label = paste0("Correlation = ",round(correlation, 2))) +
  labs(title = "Scatter Plot of Time by Order with Fitted \nLinear=Red and Quadratic=Blue Regression Li
  geom_smooth(method=lm,formula = y~poly(x,2),col="Blue",se=F)
```



The preceding scatter plot does shows only a weak positive linear relationship between Order and Time with a small correlation=0.2. However, the plot does show a plausible quadratic relationship between Order and Time.

```
##Create new Order^2 variable
df_eff$Order2<-df_eff$Order^2

#Fit quadratic model with order and order^2
slrOrderQ<-lm(Time~Order+ Order2,data = df_eff)
summary(slrOrderQ)
```

```
##
## Call:
## lm(formula = Time ~ Order + Order2, data = df_eff)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -13.7454  -5.2223   0.8306   5.4517  11.7561
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 74.47309    2.97393  25.042  < 2e-16 ***
## Order       -0.64088    0.27998  -2.289  0.02682 *
## Order2       0.01515    0.00554   2.735  0.00889 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 6.584 on 45 degrees of freedom
## Multiple R-squared:  0.1769, Adjusted R-squared:  0.1403
## F-statistic: 4.835 on 2 and 45 DF,  p-value: 0.01253
```

A fitted quadratic regression model was significant with overall overall F test p-value=0.013 and all coefficients having p-values less than .05. Thus, we decided to include both Order and Order^2 as additive covariates in the following full three factor interaction model.

```
#added covariates Order to model with 3 factor interaction
aov_three_order_eff <- aov(lm_three_order_eff <- lm(Time ~ Brand*Temp*Stirred + Order+ Order2, data = d
summary(lm_three_order_eff)
```

```
##
## Call:
## lm(formula = Time ~ Brand * Temp * Stirred + Order + Order2,
##     data = df_eff)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.7439 -0.3384  0.0535  0.4062  2.4811
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 76.948590   0.841277  91.466  < 2e-16 ***
## Brandstore                   0.999417   0.775764   1.288  0.20634
## Temp23                      -3.844322   0.822153  -4.676 4.50e-05 ***
## Temp40                     -10.482814   0.777534 -13.482 3.35e-15 ***
## Stirredno                    2.979481   1.086886   2.741  0.00968 **
## Order                       -0.072507   0.060334  -1.202  0.23776
## Order2                       0.001192   0.001066   1.118  0.27128
## Brandstore:Temp23           -7.296361   1.128891  -6.463 2.17e-07 ***
## Brandstore:Temp40           -7.360840   1.184684  -6.213 4.56e-07 ***
## Brandstore:Stirredno        -0.424657   1.099972  -0.386  0.70186
## Temp23:Stirredno             1.227466   1.123928   1.092  0.28246
## Temp40:Stirredno             2.125787   1.109188   1.917  0.06374 .
## Brandstore:Temp23:Stirredno -2.037035   1.566827  -1.300  0.20231
## Brandstore:Temp40:Stirredno -4.764555   1.615208  -2.950  0.00572 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.083 on 34 degrees of freedom
## Multiple R-squared:  0.9832, Adjusted R-squared:  0.9767
## F-statistic: 152.8 on 13 and 34 DF,  p-value: < 2.2e-16
```

```
library(car)
Anova(aov_three_order_eff, type=3) # type 3 SS
```

```
## Anova Table (Type III tests)
##
## Response: Time
##                  Sum Sq Df   F value    Pr(>F)
## (Intercept)      9812.8  1 8366.1115 < 2.2e-16 ***
```

```
## Brand                1.9  1    1.6597  0.206340
## Temp               222.0  2   94.6345 1.274e-14 ***
## Stirred              8.8  1    7.5147  0.009685 **
## Order                1.7  1    1.4442  0.237763
## Order2               1.5  1    1.2506  0.271279
## Brand:Temp          60.8  2   25.9065 1.461e-07 ***
## Brand:Stirred        0.2  1    0.1490  0.701856
## Temp:Stirred         4.3  2    1.8491  0.172851
## Brand:Temp:Stirred  10.3  2    4.3990  0.019996 *
## Residuals           39.9 34
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```