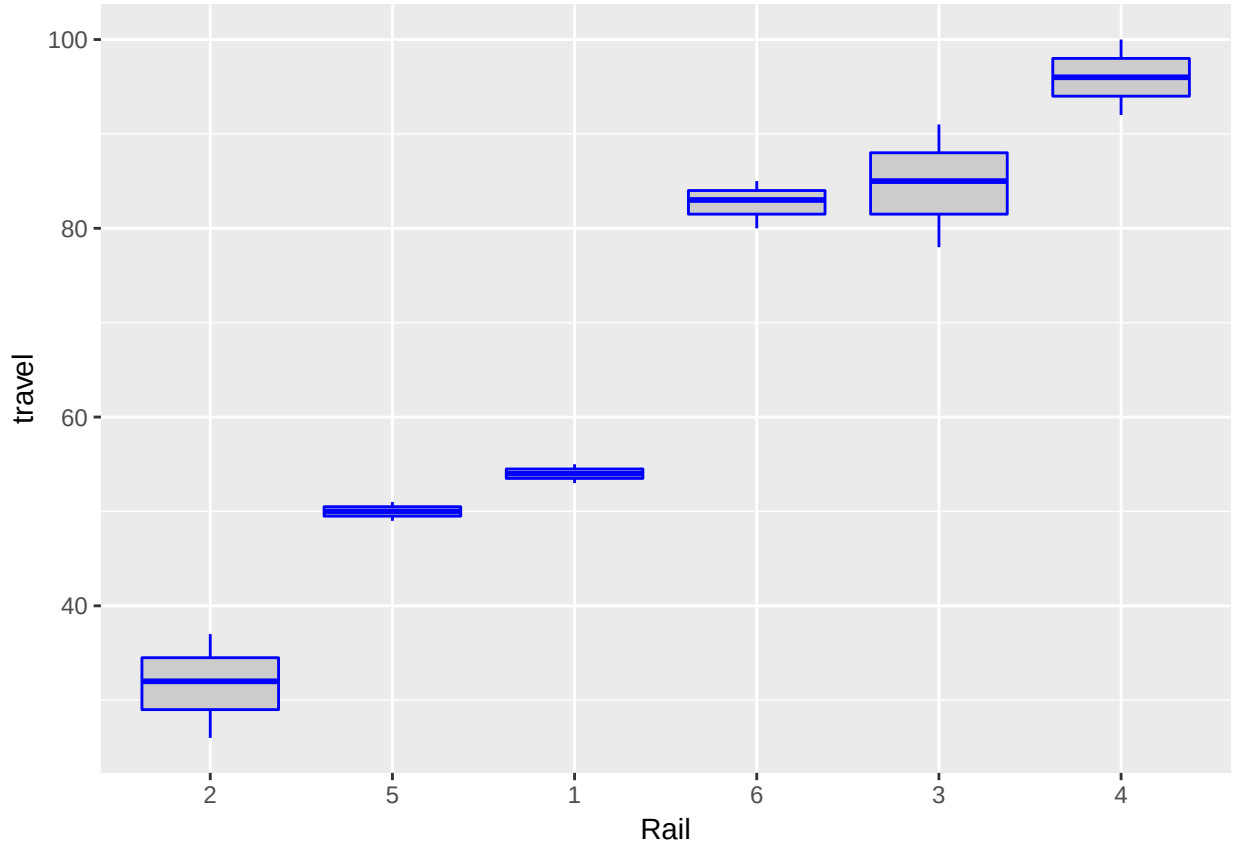
Coding

1

Visualize the data.

```
library("nlme")
library("ggplot2")

Raildata = Rail
ggplot(Raildata, aes(x=Rail, y=travel)) +
    geom_boxplot(fill="grey80", color="blue")
```



(a). Here's the mean `u`, effects `effects` and test information of fixed effect model:

```
library(dplyr)
u = mean(Raildata$travel)
effects = Raildata %>%
        group_by(Rail) %>%
        summarise(means=mean(travel)-u)
print(u)
```

```
## [1] 66.5
```

```
print(effects)
```

```
## # A tibble: 6 x 2
```

```
##    Rail     means
##   <ord>     <dbl>
## 1     2 -34.83333
## 2     5 -16.50000
## 3     1 -12.50000
## 4     6  16.16667
## 5     3  18.16667
## 6     4  29.50000
```

```
summary(aov(travel~Rail, Raildata))
```

```
##             Df Sum Sq Mean Sq F value   Pr(>F)
## Rail         5   9310  1862.1   115.2 1.03e-09 ***
## Residuals   12    194    16.2
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

(b). Fitted model:

```
library(lme4)
Rail.mixed = lmer(travel ~ 1 + (1|Rail), Raildata)
summary(Rail.mixed)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: travel ~ 1 + (1 | Rail)
##    Data: Raildata
##
## REML criterion at convergence: 122.2
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -1.61883 -0.28218  0.03569  0.21956  1.61438
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Rail     (Intercept) 615.31   24.805
##  Residual              16.17    4.021
## Number of obs: 18, groups:  Rail, 6
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)    66.50      10.17   6.538
```

(c).Use the fomula like in 1.2(b) to calculate the BLUPs and compare with results in 2.1(a), we can find that BLUPs is a little shrinked towards zero.

```
sigma_u = 24.805
sigma = 4.021
u = 66.50
BLUPs = Raildata %>%
            group_by(Rail) %>%
            summarise(effects = 3*sigma_u^2/(sigma^2+3*sigma_u^2) * (mean(travel)-u))
print(BLUPs)
```

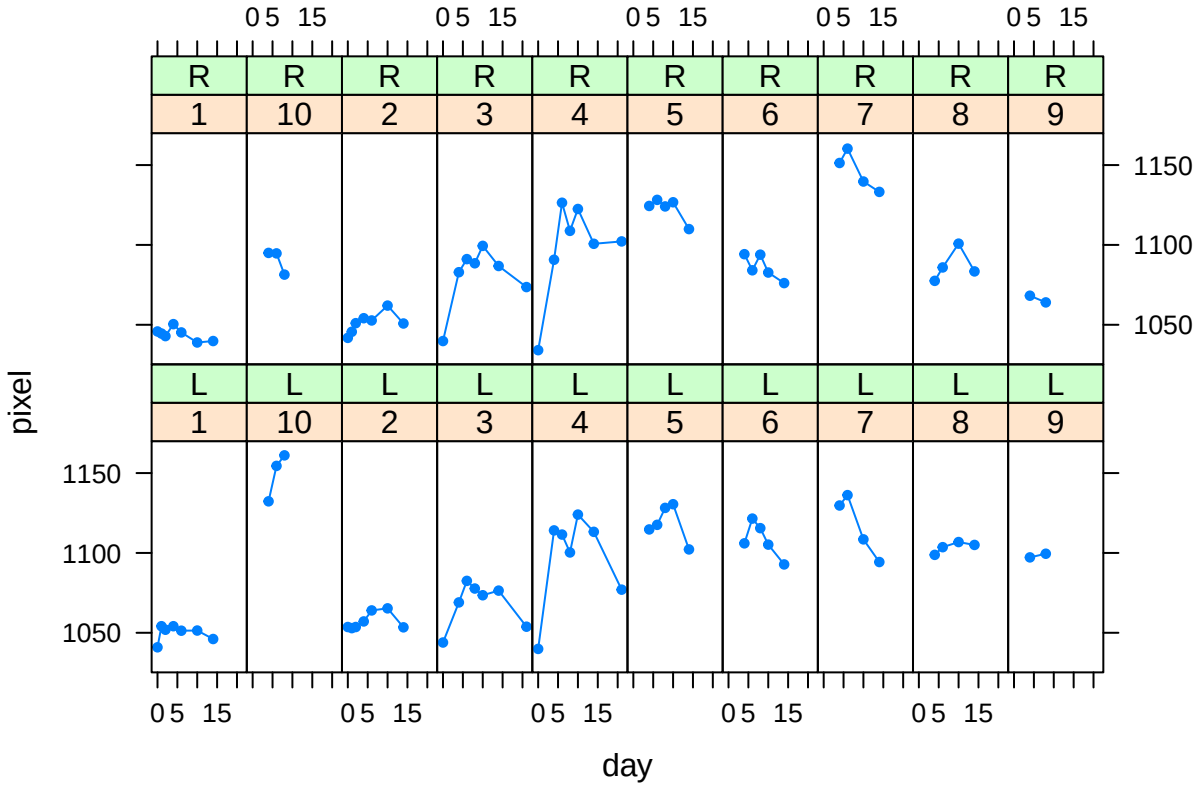
```
## # A tibble: 6 x 2
##    Rail   effects
##   <ord>     <dbl>
```

```
## 1      2 -34.53087
## 2      5 -16.35673
## 3      1 -12.39146
## 4      6  16.02629
## 5      3  18.00892
## 6      4  29.24384
```

2

(a). Visualize the data.

```
library(lattice)
data("Pixel")
xyplot(pixel ~ day | Dog + Side, data=Pixel, type='o', pch=20)
```



(b). We regard the two β_1 in this question as a typo, we fit three fixed effects $\beta_0, \beta_1, \beta_2$. Here's the result, it says that the estimates for $\beta_0, \beta_1, \beta_2$ are 1074.496, 4.87216 and -0.24739. And for the random effect, for `Dog` level, the standard deviation is 22.82; for `Side` within `Dog`, std is 15.70 and for the random error, the std is `12.92`.

```
D = mutate(Pixel,day2=day^2)
fit = lmer(pixel~day+day2+(1|Dog/Side), data=D)
summary(fit)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: pixel ~ day + day2 + (1 | Dog/Side)
##    Data: D
```

```
##
## REML criterion at convergence: 864.8
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.8639 -0.4810  0.0653  0.5333  1.9336
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Side:Dog (Intercept) 246.5    15.70
##  Dog      (Intercept) 520.8    22.82
##  Residual             166.8    12.92
## Number of obs: 102, groups:  Side:Dog, 20; Dog, 10
##
## Fixed effects:
##               Estimate Std. Error t value
## (Intercept) 1074.49600    8.77583  122.44
## day            4.87216    0.82537    5.90
## day2          -0.24739    0.04222   -5.86
##
## Correlation of Fixed Effects:
##      (Intr) day
## day  -0.353
## day2  0.294 -0.945
```