Dallin Romney
Design of Experiments

Statistical Process Control

Part I: Statistical Process Control

1. Twenty-five parts are sampled each day and found to have an average width of 2 inches, with a standard deviation of 0.1 inches. What are the control limits that include 99.73% of the sample means?

   99.73% corresponds with 3σ quality – 3 standard deviations in each direction. Thus, the control limits are 2 ± 3·0.1/sqrt(n = 25) = **1.94" Lower Control Limit** and **2.06" Upper Control Limit**. This assumes the sampling follows a normal distribution.

2. Several samples of size $n = 8$ have been taken from today's production of parts. The average part was 3 yards in length and the average sample range was 0.015 yards. Find the 99.73% upper and lower control limits.

   n = 8 → from table, A2 = 0.373 → control limits = 3 ± 0.373·0.015 = **Lower Control Limit of 2.9944 yards** and **Upper Control Limit of 3.0056 yards**.

3. The average range of a process is 10 lbs. The sample size is 10. Develop upper and lower control limits on the *range*.

   On the range → R chart → n = 10 → from table, D_3 = 0.223 and D_4 = 1.777 → $D_3 \cdot r < R < D_4 \cdot r$ → control limits of **0.223·10 = 2.23 lbs. Lower Control Limit** and 1.777·10 = **17.78 lbs. Upper Control Limit.**

Statistical Process Control Project

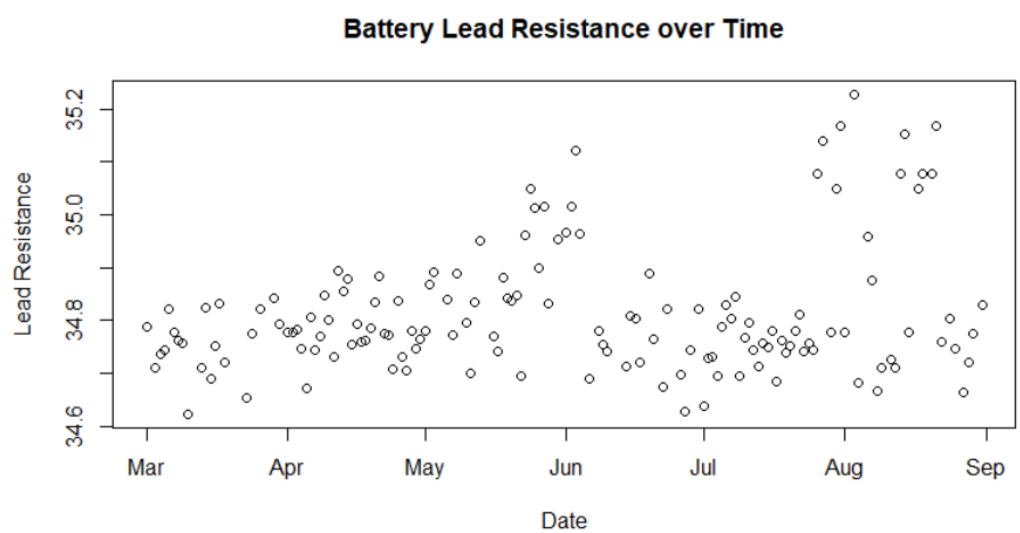
4. The Consumer Product Safety Commission (CPSC) was very satisfied with your firm's work in the hoverboard problem earlier this semester. They connected you with the supplier of the batteries for Brand D. The company now needs help to explain why many of the batteries are defective. Your firm will use its extensive knowledge of statistical process control to identify where the problems may lie and what they can do to keep their process in control. They are especially interested in finding main causes of variability to address the issues. The manufacturer has supplied you with some of their quality control measurements (n=5 units in each of 147 samples over 6 months) for the resistance in battery lead connections, determined to be a major source of fault. These data are found on Canvas, *hoverBatteriesDF.csv*. Included in these data are the day of the month and month of the sampled measurement. The company's records aren't super, but sometime during the process the company switched suppliers for a major component. A few months earlier the plant closed for annual maintenance and the machine creating lead connectors

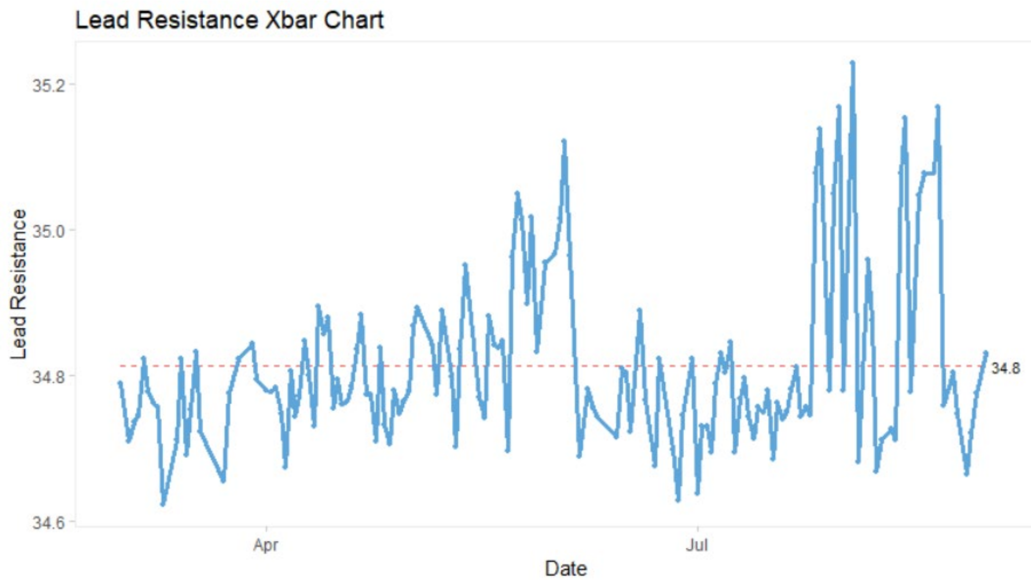
went through extensive upgrades. You suspect these events may have changed the process. Identify these key dates (based on process changes) and comment on the process before and after. Determine which type of control charts to use and discuss how you would maintain better control of the process in the future.

See plots below. Standard deviation and range data are not provided so I will use an xbar chart. The standard deviation of the means is 0.1207 and the average lead resistance is 34.81. Since the sample size is 5, the control limits for 3σ control would be 34.8 ± 3·0.1207/sqrt(5) → LCL = 34.65, UCL = 34.97.

The process appears to remain within the 3σ limits except for after two key dates. The first date is around May 30th. The second is about July 26. Whichever upgrades occurred at the ends of May and July seemed to have caused significant variance in lead resistance for short periods of time. The May incident seems to have been corrected somehow in early June, and the July incident seems to have been similarly corrected in mid-August.

To prevent future issues like this, I would recommend testing a large portion of battery testers (probably greater than about 20) after major changes in the manufacturing process to ensure that the lead resistance variability has not greatly increased and that the resistance itself is within spec. New variability could be cause by differences in timing between equipment (integration!), or badly calibrated and/or poorly set up equipment.




Lead Resistance Xbar Chart
35.2
35.0
34.8
34.6
Lead Resistance
34.8
Apr
Jul
Date

```
########################################
# Dallin Romney - u1087199             #
# Design of Experiments Homework 5     #
# March 21, 2019                       #
########################################

rm(list = ls()) # Clear workspace
cat("\014")     # Clear console (control + L)
install.packages('qicharts2')
library(qicharts2)

############## PART II Project: Batteries ##############

# Read in and organize data
batteryData = read.csv("C:/Users/Dalli/Google Drive/School/Design of Experiments/Homework/HW5/hoverBatteriesDF.csv")
month          = batteryData$month
date           = batteryData$date
leadResistance = batteryData$leadResistance

dates = as.Date(paste0("2019-", month, "-", date)) # Change numbers to dates
batteryData$dates = dates

# Plot resistances over time and xbar control chart
plot(dates, leadResistance, xlab = 'Date', ylab = 'Lead Resistance', main = 'Battery Lead Resistance over Time')

qic(y = leadResistance, data = batteryData, chart = 'xbar', x = dates, xlab = 'Date', ylab = "Lead Resistance", title = 'Lead Resistance Xbar Chart')
sd(leadResistance)
mean(leadResistance)
```