1 Control charts: role of location and variation Statistics

As it is important to consider both location and variation with inferential statistics, it is also the basis for detecting process stability with SPC charting techniques. Assignable causes for variation may be detected in plots (or charts) either or both the location and variation statistic. Depending upon the type of chart used in a given case, one or both of these plots of location and variation statistics over time reveal the behavior of the process under study.

It is important and desirable to sustain a state of control over both the process mean and variance, whether one is dealing with a manufacturing process or a measurement system. In any case, the most desirable state is one in which predictable output is the norm. For a process to be predictable, it must be free of assignable cause and the observed variation must only include common cause variation, or random (Gaussian) error.

Control charts provide a graphical means of depicting the output of a process over time, such that a process that is in a state of statistical control will show predictable behavior on the control chart. There are eight tests[2] for special (assignable) causes:

1. 1 point more than $3s$ from center line
2. 9 points in a row on same side of center line
3. Six points in a row, all increasing or all decreasing
4. Fourteen points in a row, alternating up and down
5. 2 out of 3 points $> 2s$ from center line (same side)
6. 4 out of 5 points $> 1s$ from center line (same side)
7. 15 points in a row within $1s$ of center line (either side)
8. 8 points in a row $> 1s$ from center line (either side)

The absence of any of the above conditions indicate a state of statistical control. If any of the above tests are evident in a control chart, then there is evidence of an assignable cause above and beyond random variation. The control chart reveals nothing else: further investigation is necessary to determine the assignable cause(s).

1.1 The $\bar{x}$ and R chart

The $\bar{x}$ and R chart is used here with the Gaussian Resistor data as collected by Dave on the EEVblog. The $\bar{x}$ and R chart for subgroup means ($\bar{x}$ chart) and subgroup ranges (R chart) is ideally presented on one page. Interpreting both charts together allows you to track both process center and process variation and detect the presence of special causes. An in-control process exhibits only random variation within the control limits. An out-of-control process exhibits unusual variation, which may be due to the presence of special causes.

```
> xrdata <- read.csv("GR-raw-subgroups.csv", header = TRUE)

> library(qcc)

Package 'qcc', version 2.0.1
Type 'citation("qcc")' for citing this R package in publications.

> attach(xrdata)
> subgroups <- qcc.groups(Zeroed_Resistance, Subgroup)
> obj <- qcc(subgroups, type = "xbar")

> subgroups <- qcc.groups(Zeroed_Resistance, Subgroup)
> obj <- qcc(subgroups, type = "R")
> detach(xrdata)
```

The R chart should be inspected first: it must be in control in order to interpret the $\bar{x}$ chart because the control limits are calculated considering both the process variation and the location at which it is centered.

- When the R chart is not in control, the control limits on the $\bar{x}$ chart will be inaccurate and may falsely indicate an out of control condition. In this case, the lack of control will be due to unstable variation rather than actual changes in the process center.

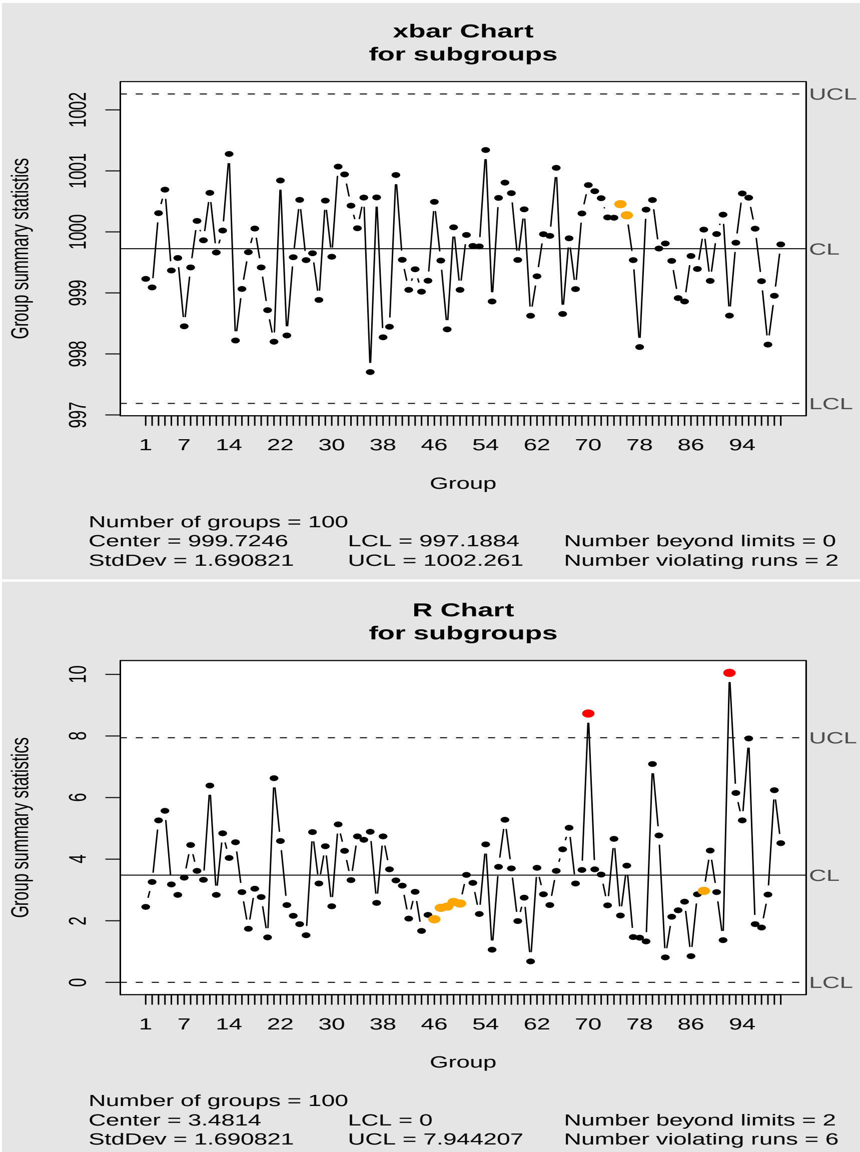

Figure 1: $\bar{x}$ and R chart for *Gaussian Resistor* data

- When the R chart is in control, you can be sure that an out- of-control $\bar{x}$ chart is due to changes in the process center.

Well we can see clearly that there are two out-of-control (red - Test 1 failure) points in the *R* chart of the *Gaussian Resistor* data, and 6 more (yellow - Tests 2 through 8) points that violate the conditions of stability for a process that is in statistical control. Very interesting results! Though the overall appearance of the charts indicate a pretty good process, the analysis reveals that there is evidence of assignable cause - i.e. non-random variation. Though the process is well within specification, there is still room for improvement - to identify and remove all sources of non-random variation.

References

[1] L.S. Nelson. The Shewhart control chart-tests for special causes. *Journal of Quality Technology*, 16(4):237–239, 1984.