Control Charts

By Praveen Gupta

Used correctly, control charts aren't wall adornments, but money-saving tools.

Dr. Walter Shewhart invented control charts in the mid-1920s while working for AT&T Bell Laboratories. His foresight is still prevalent today.

The control chart is a tool used to evaluate variation in a process and determine whether the variation is "usual" or "unusual." It compares actual variation in a production process with established variation limits based on the historical statistical performance of the process. Control charts indicate when to adjust the process, when to leave it alone, and when to shut it down. And the decision whether to use them must be an economic one. If control limits are outside the specification limits, it may be expensive to control the process.

It is well known that most processes tend to produce output that is centered around a performance value. In other words, most of the value of a characteristic tends to cluster around the performance value, whatever it may be, and only a few away from it. This is represented by the bell-shaped curve, also known as normal distribution. Control charts are interpreted based on the probabilities of the normal distribution. Control charts tell us whether the probability of producing product using a given process is following normal distribution. If not, the operator must adjust the process.

Therefore, a control chart evaluates variation in a process for normal distribution around a target (typical value) and control limits (acceptable variation from the target). When the variation exceeds the probability of producing product at a target value (0.27 percent or less), the cause of the variation appears to be identifiable, or is considered to be "assignable." When the variation is such that the probability of producing product at a target value is more than 0.27 percent, the cause of the variation becomes difficult to determine and is considered "random."

In many instances control charts are "produced" at the request of a customer. This can backfire. A third company may find the charts ineffective because they were not used properly. And employees will quickly tire of tracking worthless data. Ideally, control charts must be used when it is economic to control a process. (Indeed, a control chart, properly used, can always become an economic tool.)

Control charts must be used when a process has been properly characterized in terms of its statistical variation. All the assignable causes must be removed before using a control chart to monitor a process. In reality, the charts are often established with assignable causes present in the process. If assignable causes are present, the process will have to be shut down frequently, and the chart will become a nuisance to management and ignored by operators. Therefore, control charts must be established when the process is under statistical control, that is, when only random causes are present. No known problem should exist that could cause variation beyond the control limits.

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Control charts are classified into two categories: "variable" and "attribute." Which type of chart is used is based on the type of data collected. Examples of variable data include time, height, thickness, temperature, pressure, current, voltage, and power. Examples of attribute data are good or bad, pass or fail, high or low, accept or reject, and OK or not OK, etc. Variable-data charts are used for processes that are complex and continuous in nature, while attribute-data charts are used to control processes that are mechanical and less complex, such as assembly processes. The table lists several common control charts and their applications.

Chart Type	Application
X bar, R bar chart	For collecting data on a small-sample subgroup or if the standard deviation is unknown. Use for electronic or mechanical parts.
X bar, S chart	When standard deviation is known and sample size is about 5.
X bar, R chart	When collecting data on a sample of units is impractical, measurements on individual units are used.
U chart	Plotting average number of defects observed in a sample.
N chart	When number of defective units in a sample is plotted for go and no-go inspection or test.
P chart	When the percent data (proportion defective) is used as a measure of process performance.
C chart	For small quantity production, the count of defects in a single unit of production of constant size.

Control Limits

$\bar{\bar{X}} = \text{Sum}(\bar{x})/k$

$UCL_x = \bar{\bar{X}} + A_2\bar{R}$

$LCL_x = \bar{\bar{X}} - A_2\bar{R}$

$UCL_r = D_4\bar{R}$

Where k is number of subgroups

Factors for Control Limits

n	A_2	D_4
2	1.88	3.268
3	1.023	2.574
4	0.729	2.282
5	0.577	2.114
6	0.483	2.004

Figure 1. Control Chart Limits

The methods for constructing the various control charts are quite similar. The formulas for calculating control limits may vary slightly for the control charts listed in the table, but the concept is essentially the same for each. Figure 1 shows an example of how to calculate control limits for a control chart. The formulas for calculating control limits for various control charts can be found in any statistical quality control book or by using statistical analysis/control chart software.

Creating a Control Chart

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Before a control chart is created, the process must be in statistical control, that is, there must be no assignable causes or known problems present. The following is a list of steps to create a control chart:

1. Determine the quality characteristic to be controlled or monitored.
2. Take an adequate number of samples to establish a baseline.
3. Choose the appropriate control chart for plotting data.
4. Compute mean line and control limits.
5. Establish a location to display the control chart.
6. Train operators to plot and interpret the chart.
7. Collect data using samples at defined intervals or frequencies.
8. Plot data on control charts.
9. Analyze the results for each sample.
10. Interpret the results and take necessary action.

An example of an X bar and R control chart is shown in Figure 2.

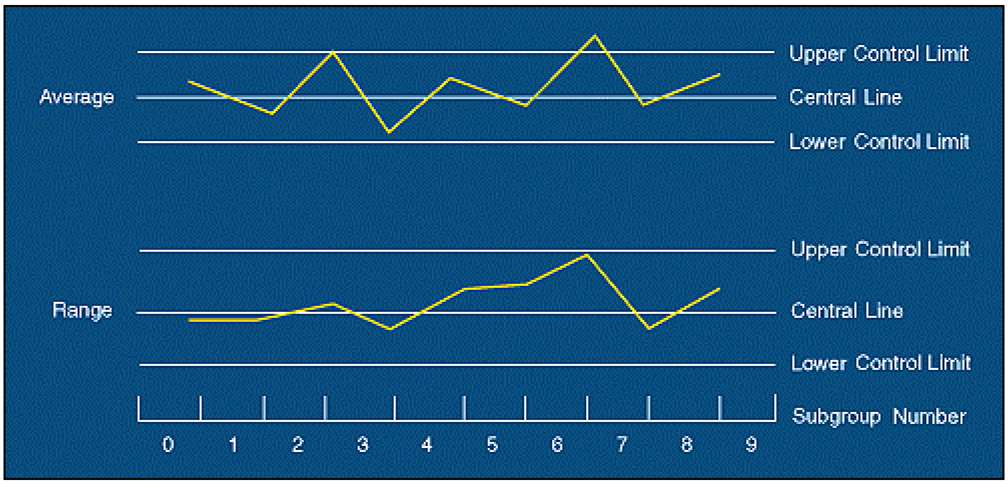

Figure 2. Example of $\bar{X}$ and R Chart

Interpreting control charts correctly is necessary to accurately determine variation in a process. Using the sample data, variation is determined based on the probability of producing acceptable product. Several rules for interpreting control charts are widely known and should be used to determine whether the process is out of control:

1. Data point is beyond control limits.
2. Nine points in a row on a side of centerline.
3. Six points in a row increasing or decreasing.
4. Fourteen points in a row alternating up and down.
5. Two out of three points in a row beyond two sigma.
6. Four out of five points in a row beyond one sigma.
7. Fifteen points in a row within one sigma.
8. Eight points in a row on both sides of the centerline within two sigma.

By adhering to the above rules, the appropriate actions can be initiated. If points are beyond the control limits, there are several possible causes: The control limits may be in error, process performance may have changed, or the measurement system may have changed. If patterns or trends are within control limits, this can be an

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indicator of an out-of-control condition, that is, some known or assignable problem may have been introduced to the process. Runs, (points lined on one side of the process mean) could indicate a shift in the process mean. Finally, any obvious nonrandom pattern indicates the presence of an assignable cause requiring immediate attention.

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