Title

qc — Quality control charts

Syntax

Draw a c chart

`cchart` *defect_var unit_var* [, *cchart_options*]

Draw a p (fraction-defective) chart

`pchart` *reject_var unit_var ssize_var* [, *pchart_options*]

Draw an R (range or dispersion) chart

`rchart` *varlist* [*if*] [*in*] [, *rchart_options*]

Draw an $\overline{X}$ *(control line) chart*

`xchart` *varlist* [*if*] [*in*] [, *xchart_options*]

Draw vertically aligned $\overline{X}$ *and R charts*

`shewhart` *varlist* [*if*] [*in*] [, *shewhart_options*]

cchart_options	Description
Main	
`nograph`	suppress graph
Plot	
connect_options	affect rendition of the plotted points
marker_options	change look of markers (color, size, etc.)
marker_label_options	add marker labels; change look or position
Control limits	
`clopts(`*cline_options*`)`	affect rendition of the control limits
Add plots	
`addplot(`*plot*`)`	add other plots to the generated graph
Y axis, X axis, Titles, Legend, Overall	
twoway_options	any options other than `by()` documented in [G-3] ***twoway_options***

pchart_options	Description
Main	
stabilized	stabilize the p chart when sample sizes are unequal
nograph	suppress graph
generate(*newvar*$_f$ *newvar*$_{\mathrm{lcl}}$ *newvar*$_{\mathrm{ucl}}$)	store the fractions of defective elements and the lower and upper control limits
Plot	
connect_options	affect rendition of the plotted points
marker_options	change look of markers (color, size, etc.)
marker_label_options	add marker labels; change look or position
Control limits	
clopts(*cline_options*)	affect rendition of the control limits
Add plots	
addplot(*plot*)	add other plots to the generated graph
Y axis, X axis, Titles, Legend, Overall	
twoway_options	any options other than by() documented in [G-3] ***twoway_options***

rchart_options	Description
Main	
std(#)	user-specified standard deviation
nograph	suppress graph
Plot	
connect_options	affect rendition of the plotted points
marker_options	change look of markers (color, size, etc.)
marker_label_options	add marker labels; change look or position
Control limits	
clopts(*cline_options*)	affect rendition of the control limits
Add plots	
addplot(*plot*)	add other plots to the generated graph
Y axis, X axis, Titles, Legend, Overall	
twoway_options	any options other than by() documented in [G-3] ***twoway_options***

xchart_options	Description
Main	
std(#)	user-specified standard deviation
mean(#)	user-specified mean
lower(#) upper(#)	lower and upper limits of the X-bar limits
nograph	suppress graph
Plot	
connect_options	affect rendition of the plotted points
marker_options	change look of markers (color, size, etc.)
marker_label_options	add marker labels; change look or position
Control limits	
clopts(*cline_options*)	affect rendition of the control limits
Add plots	
addplot(*plot*)	add other plots to the generated graph
Y axis, X axis, Titles, Legend, Overall	
twoway_options	any options other than by() documented in [G-3] ***twoway_options***

shewhart_options	Description
Main	
std(#)	user-specified standard deviation
mean(#)	user-specified mean
nograph	suppress graph
Plot	
connect_options	affect rendition of the plotted points
marker_options	change look of markers (color, size, etc.)
marker_label_options	add marker labels; change look or position
Control limits	
clopts(*cline_options*)	affect rendition of the control limits
Y axis, X axis, Titles, Legend, Overall	
combine_options	any options documented in [G-2] **graph combine**

Menu

cchart

Statistics > Other > Quality control > C chart

pchart

Statistics > Other > Quality control > P chart

rchart

Statistics > Other > Quality control > R chart

xchart

Statistics > Other > Quality control > X-bar chart

shewhart

Statistics > Other > Quality control > Vertically aligned X-bar and R chart

Description

These commands provide standard quality-control charts. `cchart` draws a c chart; `pchart`, a p (fraction-defective) chart; `rchart`, an R (range or dispersion) chart; `xchart`, an $\overline{X}$ (control line) chart; and `shewhart`, vertically aligned $\overline{X}$ and R charts.

Options

Main

`stabilized` stabilizes the p chart when sample sizes are unequal.

`std(#)` specifies the standard deviation of the process. The R chart is calculated (based on the range) if this option is not specified.

`mean(#)` specifies the grand mean, which is calculated if not specified.

`lower(#)` and `upper(#)` must be specified together or not at all. They specify the lower and upper limits of the $\overline{X}$ chart. Calculations based on the mean and standard deviation (whether specified by option or calculated) are used otherwise.

`nograph` suppresses the graph.

`generate(`$newvar_f$ $newvar_{\mathrm{lcl}}$ $newvar_{\mathrm{ucl}}$`)` stores the plotted values in the p chart. $newvar_f$ will contain the fractions of defective elements; $newvar_{\mathrm{lcl}}$ and $newvar_{\mathrm{ucl}}$ will contain the lower and upper control limits, respectively.

Plot

connect_options affect whether lines connect the plotted points and the rendition of those lines; see [G-3] ***connect_options***.

marker_options affect the rendition of markers drawn at the plotted points, including their shape, size, color, and outline; see [G-3] ***marker_options***.

marker_label_options specify if and how the markers are to be labeled; see [G-3] ***marker_label_options***.

Control limits

`clopts(`*cline_options*`)` affects the rendition of the control limits; see [G-3] ***cline_options***.

Add plots

`addplot(`*plot*`)` provides a way to add other plots to the generated graph. See [G-3] ***addplot_option***.

Y axis, X axis, Titles, Legend, Overall

twoway_options are any of the options documented in [G-3] ***twoway_options***, excluding `by()`. These include options for titling the graph (see [G-3] ***title_options***) and for saving the graph to disk (see [G-3] ***saving_option***).

combine_options (shewhart only) are any of the options documented in [G-2] **graph combine**. These include options for titling the graph (see [G-3] ***title_options***) and for saving the graph to disk (see [G-3] ***saving_option***).

Remarks and examples

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Control charts may be used to define the goal of a repetitive process, to control that process, and to determine if the goal has been achieved. Walter A. Shewhart of Bell Telephone Laboratories devised the first control chart in 1924. In 1931, Shewhart published *Economic Control of Quality of Manufactured Product*. According to Burr, "Few fields of knowledge have ever been so completely explored and charted in the first exposition" (1976, 29). Shewhart states that "a phenomenon will be said to be controlled when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future. Here it is understood that prediction within limits means that we can state, at least approximately, the probability that the observed phenomenon will fall within given limits" (1931, 6).

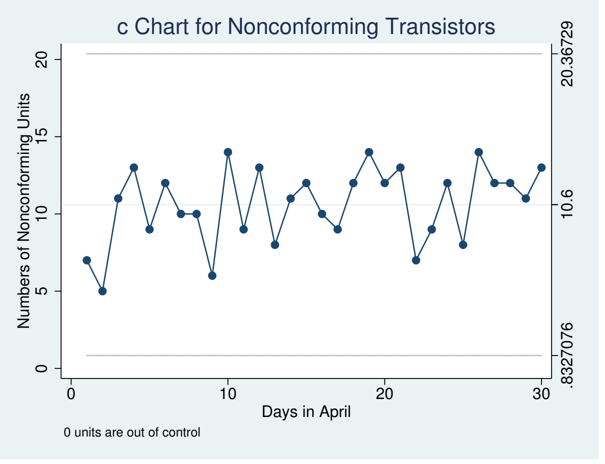
For more information on quality-control charts, see Burr (1976), Duncan (1986), Harris (1999), or Ryan (2000).

▷ Example 1: cchart

cchart graphs a c chart showing the number of nonconformities in a unit, where *defect_var* records the number of defects in each inspection unit and *unit_var* records the unit number. The unit numbers need not be in order. For instance, consider the following example dataset from Ryan (2000, 156):

```
. use http://www.stata-press.com/data/r13/ncu
. describe
Contains data from http://www.stata-press.com/data/r13/ncu.dta
  obs:            30
 vars:             2                          31 Mar 2013 03:56
 size:           240
-------------------------------------------------------------------------------
              storage   display    value
variable name   type    format     label      variable label
-------------------------------------------------------------------------------
day             float   %9.0g                 Days in April
defects         float   %9.0g                 Numbers of Nonconforming Units
-------------------------------------------------------------------------------
Sorted by:
. list in 1/5

     +---------------+
     | day   defects |
     |---------------|
  1. |   1         7 |
  2. |   2         5 |
  3. |   3        11 |
  4. |   4        13 |
  5. |   5         9 |
     +---------------+
```

```
. cchart defects day, title(c Chart for Nonconforming Transistors)
```



The expected number of defects is 10.6, with lower and upper control limits of 0.8327 and 20.37, respectively. No units are out of control.

◁

▷ Example 2: pchart

`pchart` graphs a p chart, which shows the fraction of nonconforming items in a subgroup, where *reject_var* records the number rejected in each inspection unit, *unit_var* records the inspection unit number, and *ssize_var* records the number inspected in each unit.

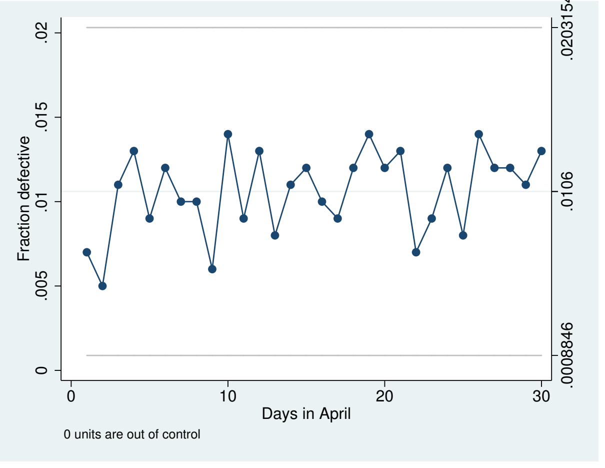
Consider the example dataset from Ryan (2000, 156) of the number of nonconforming transistors out of 1,000 inspected each day during the month of April:

```
. use http://www.stata-press.com/data/r13/ncu2
. describe
Contains data from http://www.stata-press.com/data/r13/ncu2.dta
  obs:            30
 vars:             3                          31 Mar 2013 14:13
 size:           360

              storage   display    value
variable name   type    format     label      variable label

day             float   %9.0g                 Days in April
rejects         float   %9.0g                 Numbers of Nonconforming Units
ssize           float   %9.0g                 Sample size

Sorted by:
```

```
. list in 1/5
```

	day	rejects	ssize
1.	1	7	1000
2.	2	5	1000
3.	3	11	1000
4.	4	13	1000
5.	5	9	1000

```
. pchart rejects day ssize
```



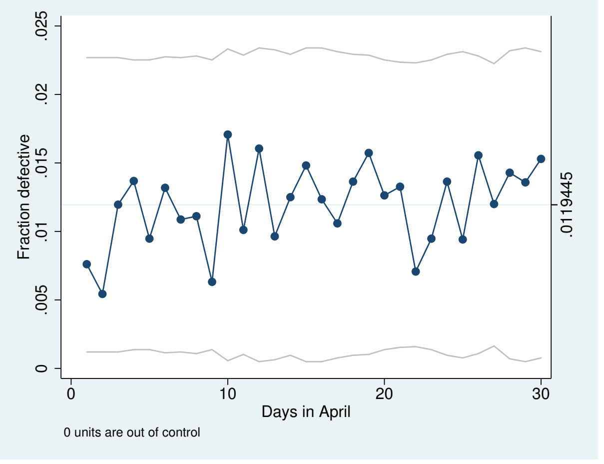
All the points are within the control limits, which are 0.0009 for the lower limit and 0.0203 for the upper limit.

Here the sample sizes are fixed at 1,000, so the `ssize` variable contains 1,000 for each observation. Sample sizes need not be fixed, however. Say that our data were slightly different:

```
. use http://www.stata-press.com/data/r13/ncu3
. list in 1/5
```

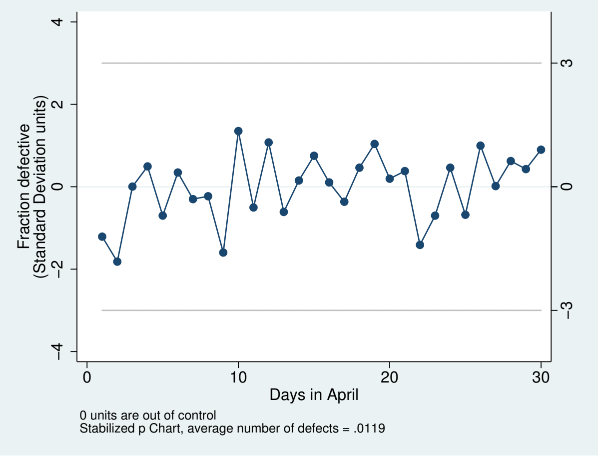
	day	rejects	ssize
1.	1	7	920
2.	2	5	920
3.	3	11	920
4.	4	13	950
5.	5	9	950

```
. pchart rejects day ssize
```



Here the control limits are, like the sample size, no longer constant. The `stabilize` option will stabilize the control chart:

```
. pchart rejects day ssize, stabilize
```



▷ Example 3: rchart

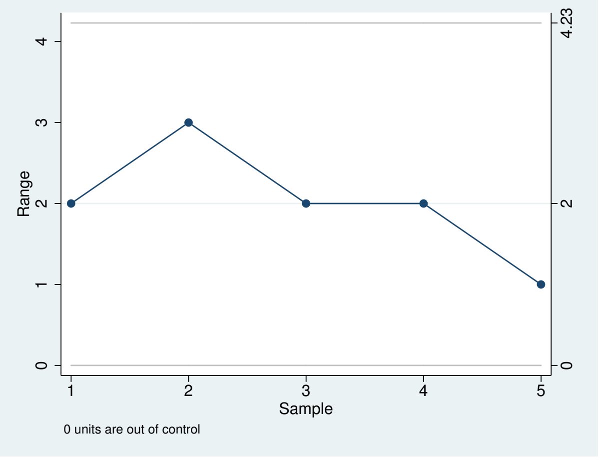
`rchart` displays an R chart showing the range for repeated measurements at various times. Variables within observations record measurements. Observations represent different samples.

For instance, say that we take five samples of 5 observations each. In our first sample, our measurements are 10, 11, 10, 11, and 12. The data are

```
. list
```

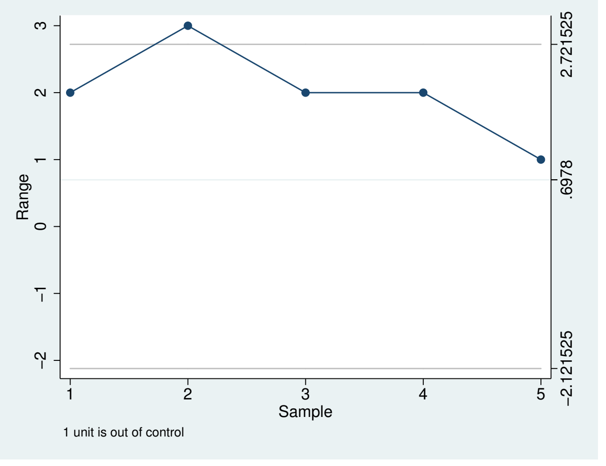
	m1	m2	m3	m4	m5
1.	10	11	10	11	12
2.	12	10	9	10	9
3.	10	11	10	12	10
4.	9	9	9	10	11
5.	12	12	12	12	13

```
. rchart m1-m5, connect(l)
```



The expected range in each sample is 2 with lower and upper control limits of 0 and 4.23, respectively. If we know that the process standard deviation is 0.3, we could specify

```
. rchart m1-m5, connect(l) std(.3)
```

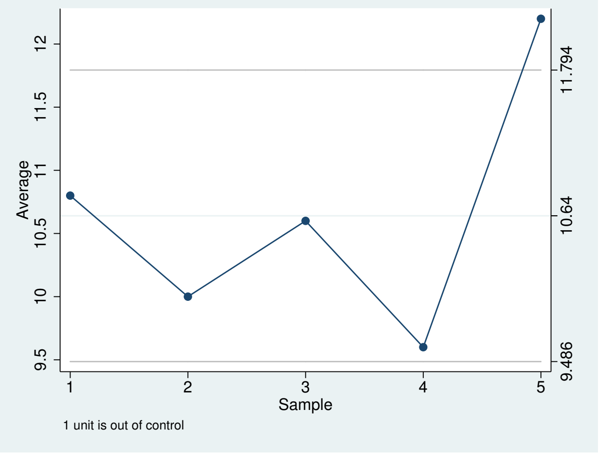


◁

▷ Example 4: xchart

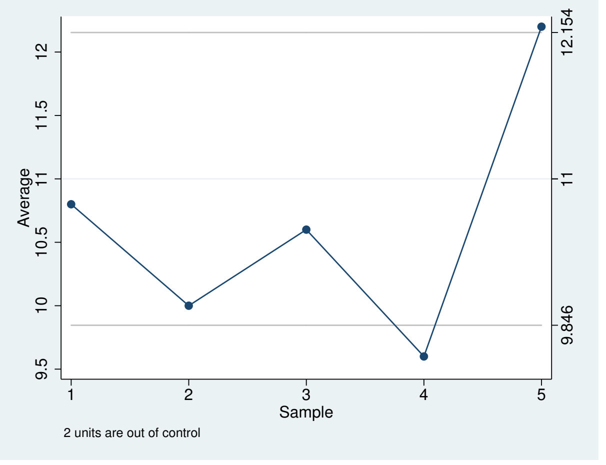
`xchart` graphs an $\overline{\mathrm{X}}$ chart for repeated measurements at various times. Variables within observations record measurements, and observations represent different samples. Using the same data as in the previous example, we type

```
. xchart m1-m5, connect(l)
```



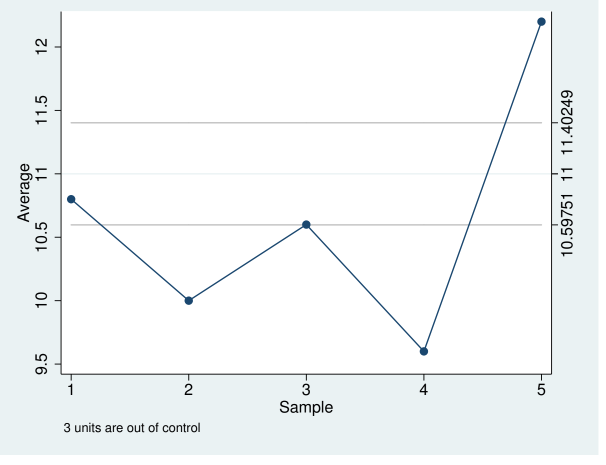
The average measurement in the sample is 10.64, and the lower and upper control limits are 9.486 and 11.794, respectively. Suppose that we knew from prior information that the mean of the process is 11. Then we would type

```
. xchart m1-m5, connect(l) mean(11)
```



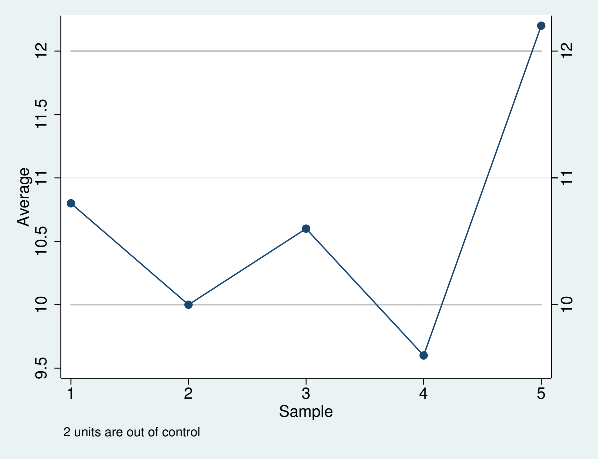
If we also know that the standard deviation of the process is 0.3, we could type

```
. xchart m1-m5, connect(l) mean(11) std(.3)
```



Finally, `xchart` allows us to specify our own control limits:

```
. xchart m1-m5, connect(l) mean(11) lower(10) upper(12)
```



◁

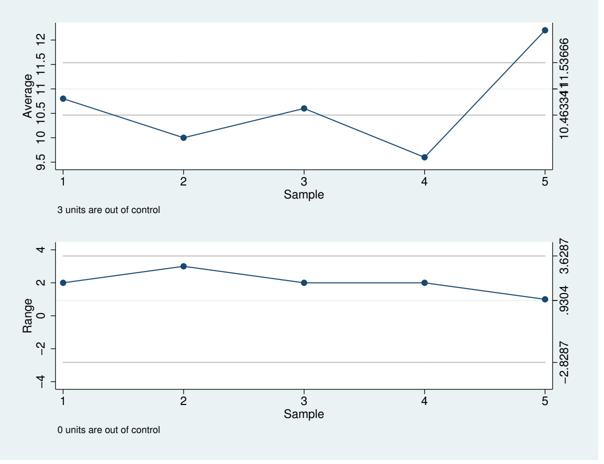
Walter Andrew Shewhart (1891–1967) was born in Illinois and educated as a physicist, with degrees from the Universities of Illinois and California. After a brief period teaching physics, he worked for the Western Electric Company and (from 1925) the Bell Telephone Laboratories. His name is most associated with control charts used in quality controls, but his many other interests ranged generally from quality assurance to the philosophy of science.

▷ Example 5: shewhart

`shewhart` displays a vertically aligned $\overline{\mathrm{X}}$ and R chart in the same image. To produce the best-looking combined image possible, you will want to use the `xchart` and `rchart` commands separately and then combine the graphs. `shewhart`, however, is more convenient.

Using the same data as previously, but realizing that the standard deviation should have been 0.4, we type

```
. shewhart m1-m5, connect(l) mean(11) std(.4)
```



◁

Stored results

cchart stores the following in r():

Scalars

r(cbar)	expected number of nonconformities
r(lcl_c)	lower control limit
r(ucl_c)	upper control limit
r(N)	number of observations
r(out_c)	number of units out of control
r(below_c)	number of units below the lower limit
r(above_c)	number of units above the upper limit

pchart stores the following in r():

Scalars

r(pbar)	average fraction of nonconformities
r(lcl_p)	lower control limit
r(ucl_p)	upper control limit
r(N)	number of observations
r(out_p)	number of units out of control
r(below_p)	number of units below the lower limit
r(above_p)	number of units above the upper limit

rchart stores the following in r():

Scalars

r(central_line)	ordinate of the central line
r(lcl_r)	lower control limit
r(ucl_r)	upper control limit
r(N)	number of observations
r(out_r)	number of units out of control
r(below_r)	number of units below the lower limit
r(above_r)	number of units above the upper limit

`xchart` stores the following in `r()`:

Scalars

`r(xbar)`	grand mean
`r(lcl_x)`	lower control limit
`r(ucl_x)`	upper control limit
`r(N)`	number of observations
`r(out_x)`	number of units out of control
`r(below_x)`	number of units below the lower limit
`r(above_x)`	number of units above the upper limit

`shewhart` stores in `r()` the combination of stored results from `xchart` and `rchart`.

Methods and formulas

For the c chart, the number of defects per unit, C, is taken to be a value of a random variable having a Poisson distribution. If k is the number of units available for estimating λ, the parameter of the Poisson distribution, and if C_i is the number of defects in the ith unit, then λ is estimated by $\overline{C} = \sum_i C_i/k$. Then

$$\text{central line} = \overline{C}$$
$$\text{UCL} = \overline{C} + 3\sqrt{\overline{C}}$$
$$\text{LCL} = \overline{C} - 3\sqrt{\overline{C}}$$

Control limits for the p chart are based on the sampling theory for proportions, using the normal approximation to the binomial. If k samples are taken, the estimator of p is given by $\overline{p} = \sum_i \widehat{p}_i/k$, where $\widehat{p}_i = x_i/n_i$, and x_i is the number of defects in the ith sample of size n_i. The central line and the control limits are given by

$$\text{central line} = \overline{p}$$
$$\text{UCL} = \overline{p} + 3\sqrt{\overline{p}(1-\overline{p})/n_i}$$
$$\text{LCL} = \overline{p} - 3\sqrt{\overline{p}(1-\overline{p})/n_i}$$

Control limits for the R chart are based on the distribution of the range of samples of size n from a normal population. If the standard deviation of the process, σ, is known,

$$\text{central line} = d_2\sigma$$
$$\text{UCL} = D_2\sigma$$
$$\text{LCL} = D_1\sigma$$

where d_2, D_1, and D_2 are functions of the number of observations in the sample and are obtained from the table published in Beyer (1976).

When σ is unknown,

$$\text{central line} = \overline{R}$$
$$\text{UCL} = (D_2/d_2)\overline{R}$$
$$\text{LCL} = (D_1/d_2)\overline{R}$$

where $\overline{R} = \sum_i R_i/k$ is the range of the k sample ranges R_i.

Control limits for the $\overline{\mathrm{X}}$ chart are given by

$$\begin{aligned} \text{central line} &= \overline{x} \\ \text{UCL} &= \overline{x} + (3/\sqrt{n})\sigma \\ \text{LCL} &= \overline{x} - (3/\sqrt{n})\sigma \end{aligned}$$

if σ is known. If σ is unknown,

$$\begin{aligned} \text{central line} &= \overline{x} \\ \text{UCL} &= \overline{x} + A_2\overline{R} \\ \text{LCL} &= \overline{x} - A_2\overline{R} \end{aligned}$$

where $\overline{R}$ is the average range as defined above and A_2 is a function (op. cit.) of the number of observations in the sample.

References

Bayart, D. 2001. Walter Andrew Shewhart. In *Statisticians of the Centuries*, ed. C. C. Heyde and E. Seneta, 398–401. New York: Springer.

Beyer, W. H. 1976. Factors for computing control limits. In Vol. 2 of *Handbook of Tables for Probability and Statistics*, ed. W. H. Beyer, 451–465. Cleveland, OH: The Chemical Rubber Company.

Burr, I. W. 1976. *Statistical Quality Control Methods*. New York: Dekker.

Caulcutt, R. 2004. Control charts in practice. *Significance* 1: 81–84.

Duncan, A. J. 1986. *Quality Control and Industrial Statistics*. 5th ed. Homewood, IL: Irwin.

Harris, R. L. 1999. *Information Graphics: A Comprehensive Illustrated Reference*. New York: Oxford University Press.

Ryan, T. P. 2000. *Statistical Methods for Quality Improvement*. 2nd ed. New York: Wiley.

Saw, S. L. C., and T. W. Soon. 1994. sqc1: Estimating process capability indices with Stata. *Stata Technical Bulletin* 17: 18–19. Reprinted in *Stata Technical Bulletin Reprints*, vol. 3, pp. 174–175. College Station, TX: Stata Press.

Shewhart, W. A. 1931. *Economic Control of Quality of Manufactured Product*. New York: Van Nostrand.

Also see

[R] **serrbar** — Graph standard error bar chart