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Control charts —

Part 5: Specialized control charts

Cartes de contrôle —

Partie 5: Cartes de contrôle particulières

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 4, *Applications of statistical methods in process management*.

ISO 7870 consists of the following parts, under the general title *Control charts*:

— *Part 1: General guidelines*

— *Part 2: Shewhart control charts*

— *Part 3: Acceptance control charts*

— *Part 4: Cumulative sum control charts*

— *Part 5: Specialized control charts*

— *Part 6: EWMA control charts*

Introduction

The Shewhart control charts as given in ISO 7870-2 aid in detection of unnatural patterns of variations in data from repetitive processes and provide criteria for detecting a lack of statistical control.

However, there may be several special situations for variables data where Shewhart control charts may be inadequate, insufficient or less efficient in detecting the unnatural patterns of variation of the process, particularly where:

a) it takes considerable time to produce an item and as such sample results are available at large intervals;

b) there are several subgroup sources that have approximately the same production rate, process average and process capability;

c) process average is changing systematically;

d) sample size is large and sequence of production is irrelevant;

e) process does not have a constant target value.

In such situations, specialized control charts are to be used.

Similarly, special situations may be encountered in dealing with attributes data. There may be situations when criticality of an incidence in a subgroup (nonconformity) is a matter of concern, but different nonconformities are having different criticality. As such, all types of nonconformities cannot be treated alike. Depending upon criticality, different ratings (weights) are required to be given to each class of nonconformity, and accordingly demerit scores are calculated. The control limits are calculated based on such demerit scores and accordingly control charts are plotted to exercise process control.

There may be situations when inspection by attributes is preferred to that by variables, from practical considerations, for controlling both the location and the variability parameters of a measureable characteristic of a process (for example, inspection by gauging). The information is also available on the number of items less than the lower specification limits (no-go gauge) as well as the number of items above upper specification limit (go gauge) in assembly operations. In such situation, a specialized pair of control charts may be used.

There may also be situations when data do not follow normal distribution. Such situations of non-normal data are quite often encountered in service industry, besides in special processes of manufacturing. In such a situation specialized control chart is to be used.

This part of ISO 7870 has been prepared to provide guidance on the use of specialized control charts to address above typical, unusual situations.

Control charts —

Part 5:
Specialized control charts

1 Scope

This part of ISO 7870 establishes a guide to the use and understanding of specialized control charts in situations where commonly used Shewhart control chart approach to the methods of statistical control of a process may either be not applicable or less efficient in detecting unnatural patterns of variation of the process.

The specialized control charts included in this part of ISO 7870 for variables data are:

a) moving average and moving range charts;

b) *z*-charts;

c) group control charts;

d) high–low control charts;

e) trend control charts;

f) control charts for coefficient of variation;

g) control charts for non-normal data.

For attributes data, specialized control charts included in this part of ISO 7870 are:

a) standardized p-charts;

b) demerit control charts;

c) control charts for inspection by gauging.

This part of ISO 7870 also provides guidance as to when each of the above control charts should be used, their control limits, advantages and limitations. Each control chart is illustrated with an example.

2 Normative references

The following referenced documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3534-2, *Statistics — Vocabulary and symbols — Part 2: Applied statistics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3534-2 and the following apply.

3.1
control chart
chart on which some statistical measure of a series of samples is plotted in a particular order to steer the process with respect to that measure and to control and reduce variation

Note 1 to entry: The particular order is usually based on time or sample number order.

Note 2 to entry: The control chart operates most effectively when the measure is a process variable which is correlated with an ultimate product or service characteristic.

[SOURCE: ISO 3534-2:2006, 2.3.1]

3.2
Shewhart control chart
control chart with Shewhart control limits intended primarily to distinguish between the variation in the plotted measure due to random causes and that due to special causes

[SOURCE: ISO 3534-2:2006, 2.3.2]

3.3
variables control chart
Shewhart control chart in which the measure plotted represents data on a continuous scale

[SOURCE: ISO 3534-2:2006, 2.3.6]

3.4
attributes control chart
Shewhart control chart in which the measure plotted represents countable or categorized data

[SOURCE: ISO 3534-2:2006, 2.3.7]

3.5
Xbar control chart
average control chart
variables control chart for evaluating the process level in terms of subgroup averages

[SOURCE: ISO 3534-2:2006, 2.3.12]

3.6
R chart
range control chart
variables control chart for evaluating variation in terms of subgroup ranges

Note 1 to entry: The value of the subgroup range, given by the symbol R, is the difference between the largest and smallest observation of a subgroup.

Note 2 to entry: The average of the range values for all subgroups is denoted by the symbol $\overline{R}$.

[SOURCE: ISO 3534-2:2006, 2.3.18]

3.7
moving average control chart
control chart for evaluating the process level in terms of the arithmetic average of each successive n observations

Note 1 to entry: This chart is particularly useful when only one observation per subgroup is available. Examples are process characteristics such as temperature, pressure and time.

Note 2 to entry: The current observation replaces the oldest of the latest n + 1 observations.

Note 3 to entry: It has the disadvantage of an unweighted carry-over effect lasting n points.

[SOURCE: ISO 3534-2:2006, 2.3.14]

3.8
moving range control chart
variables control chart for evaluating variation in terms of the range of each successive *n* observations

Note 1 to entry: The current observation replaces the oldest of the latest *n* +1 observations.

[SOURCE: ISO 3534-2:2006, 2.3.20]

3.9
z-chart
variables control chart for evaluating the process in terms of subgroup standardized normal variates

3.10
group control chart for averages
variables control chart for evaluating the process level in terms of subgroup (with several sources) highest and lowest averages with corresponding source identification

3.11
group control chart for ranges
variables control chart for evaluating the process variation in terms of subgroup (with several sources) highest ranges with corresponding source identification

3.12
high – low control chart
variables control chart for evaluating the process level in terms of subgroup largest and smallest values

3.13
trend control chart
control chart for evaluating the process level with respect to the deviation of the subgroup averages from an expected change in the process level

Note 1 to entry: The trend may be determined empirically or by regression techniques.

Note 2 to entry: A trend is an upward or downward tendency, after exclusion of the random variation and cyclical effects, when observed values are plotted in the time order of the observations.

[SOURCE: ISO 3534-2:2006, 2.3.17]

3.14
control chart for coefficient of variation
variables control chart for evaluating variation in terms of subgroup coefficient of variation

3.15
p chart
proportion or percent categorized units control chart
attributes control chart for number of units of a given classification per total number of units in the sample expressed either as a proportion or percent

Note 1 to entry: In the quality field, the classification usually takes the form of “nonconforming unit”.

Note 2 to entry: The “p” chart is applied particularly when the sample size is variable.

Note 3 to entry: The plotted measure can be expressed as a proportion or as a percentage.

[SOURCE: ISO 3534-2:2006, 2.3.11]

3.16
standardized p-chart
attributes control chart where proportions of given classification are expressed as standardized normal variates

Note 1 to entry: In this chart, the centre line is zero, upper control limit is +3 and lower control limit is −3.

3.17
demerit control chart
quality score chart
multiple characteristic control chart for evaluating the process level where different weights are apportioned to events depending on their perceived significance

[SOURCE: ISO 3534-2:2006, 2.3.23]

3.18
control chart for inspection by gauging
attributes control chart when the inspection is done by gauging and the information is available on the number of units above upper gauge limit and below lower gauge limit

4 Symbols and abbreviated terms

4.1 Symbols

n subgroup sample size

k number of subgroups

x individual measured value

$\bar{x}_i$ average value of i-th subgroup

$\bar{\bar{x}}$ average of the subgroup average values

μ true process mean value

σ true process standard deviation value

R range

$\bar{R}$ average range

s sample standard deviation

$\bar{s}$ average of subgroup sample standard deviations

p proportion or fraction of units

$\bar{p}$ average value of the proportion or fraction of units

$\mathrm{C_L}$ centre line

$\mathrm{U_{CL}}$ upper control limit

$\mathrm{L_{CL}}$ lower control limit

$\bar{X}$ average value of the variable X plotted on a control chart

x_H largest observation in a subgroup

x_L smallest observation in a subgroup

$\bar{x}_H$ average of largest observations for all subgroups

$\bar{x}_L$ average of smallest observations for all subgroups

z variable that has a normal distribution with zero mean and unit standard deviation

v coefficient of variation

$\bar{v}$ average of coefficient of variation values

4.2 Abbreviated terms

BPO business process outsourcing

CV coefficient of variation

L_{GL} lower gauge limit

U_{GL} upper gauge limit

5 Specialized control charts

The following specialized control charts for variables have been included:

a) moving average and moving range control charts;

b) *z*-charts;

c) group control charts;

d) high–low control charts;

e) trend control charts;

f) control charts for coefficient of variation;

g) control charts for non-normal data.

The following specialized control charts for attributes have been included:

a) standardized p-chart;

b) demerit control chart;

c) control chart for inspection by gauging.

6 Moving average and moving range control charts

In certain cases of industrial production it takes considerable time to produce a new item or the tests are destructive in nature. As a result, it is inconvenient to sample frequently to accumulate sample of size $n > 1$. In the meantime process average or dispersion may have changed and this may incur some appreciable loss. Under such situations subgroups, each consisting of individual observations, are used for process monitoring.

In these situations, use of moving averages and moving ranges instead of Shewhart control charts has been suggested. Moving averages of k subgroups (each of size one) are obtained as follows. Initially, the values of first k subgroups are averaged. Then in the second step the value for the first subgroup is dropped in favour of the value for $(k+1)^{th}$ subgroup and an average obtained. Next, the value for the second subgroup is dropped and the value for $(k+2)^{th}$ subgroup is included and these values are averaged, and so on. In a similar manner moving ranges are obtained. The rate of production helps to decide the number of subgroups to be considered at a time for moving average and moving range. Additionally, the lesser the magnitude of shift in process average and variation one wishes to detect, the higher will be the value of *k*.

6.1 Control limits

6.1.1 Moving range chart

$$C_L = \overline{R}$$

$$U_{CL} = D_4\overline{R}$$

$$L_{CL} = D_3\overline{R}$$

6.1.2 Moving average chart

$$C_L = \overline{\overline{x}}$$

$$U_{CL} = \overline{\overline{x}} + A_2\overline{R}$$

$$L_{CL} = \overline{\overline{x}} - A_2\overline{R}$$

where, $\overline{R}$ is the homogenized range. The values of A_2, D_3 and D_4 are given in Annex A for various sample sizes (*n*) = *k*.

6.2 Interpretation

Unlike the case of Shewhart control charts, here successive moving averages and moving ranges are not independent. Hence, in moving average and moving range control charts, runs on either side of the centre line do not have the same interpretation as is given by Shewhart control chart. However, a point beyond control limits here has the same significance as in case of Shewhart control chart. Cyclic pattern and/or increasing or decreasing trend in the moving range chart is indicative of potential for improvement. However, the assignable causes for the moving average chart and those for moving range chart may be different.

6.3 Advantages

In some situations a control chart for moving average and moving range is more efficient. It gives a warning signal earlier than with usual $(\overline{X}, R)$ charts. It is not necessary to wait until an entire new sample is accumulated. This may be important if the product is either expensive or the rate of output is small.

6.4 Limitations

Successive points are not independent. Since the probability of obtaining a run of any kind is much larger with control chart for moving average or moving range as compared to the Shewhart control charts, the traditional interpretation of runs is not valid for these control charts.

6.5 Example

The crown of the watchcase is used to adjust the time. The pin of the crown is fitted through a hole in the watch case. The diameter of the hole has to be maintained at 0,005 ± 0,001mm. Table 1 gives the data in order of production, where reaming operation is done to make the hole for the pin of crown to fit in the watchcase. It is decided to plot control charts for the moving average and moving range by averaging diameter values from 3 consecutive subgroups.

Table 1 — Subgroup results from diameter of the hole for the pin of crown

Sub group number	Hole diameter	Sum of 3 moving observations	Moving average	Moving range	Remarks
1	0,003				
2	0,005				
3	0,001	0,009	0,0030	0,004	
4	0,003	0,009	0,0030	0,004	
5	0,002	0,006	0,0020	0,002	
6	0,005	0,010	0,0033	0,003	
7	0,006	0,013	0,0043	0,004	Shift change
8	0,003	0,014	0,0047	0,003	
9	0,004	0,013	0,0043	0,003	
10	0,005	0,012	0,0040	0,002	
11	0,005	0,014	0,0047	0,001	
12	0,006	0,016	0,0053	0,001	
13	0,001	0,012	0,0040	0,005	
14	0,002	0,009	0,0030	0,005	Tool changed
15	0,007	0,010	0,0033	0,006	
16	0,001	0,010	0,0033	0,006	
17	0,003	0,011	0,0037	0,006	
18	0,004	0,008	0,0027	0,003	
19	0,003	0,010	0,0033	0,001	
20	0,001	0,008	0,0027	0,003	
21	0,006	0,010	0,0033	0,005	
22	0,005	0,012	0,0040	0,005	
23	0,004	0,015	0,0050	0,002	
24	0,002	0,011	0,0037	0,003	
25	0,001	0,007	0,0023	0,003	
Total			**0,0829**	**0,080**	

6.5.1 Control limits for moving range control chart

$$C_L = \overline{R} = \frac{0{,}080}{23} = 0{,}0035$$

$$U_{CL} = D_4 \overline{R} = 2{,}575 \times 0{,}0035 = 0{,}0090$$

$$L_{CL} = D_3\overline{R} = 0 \times 0{,}0035 = 0$$

The above values of D_3 and D_4 are taken from Annex A for n = 3. As all range values are less than U_{CL}, the value of average homogenized range is taken as 0,0035 for computation of control limits for moving average control chart.

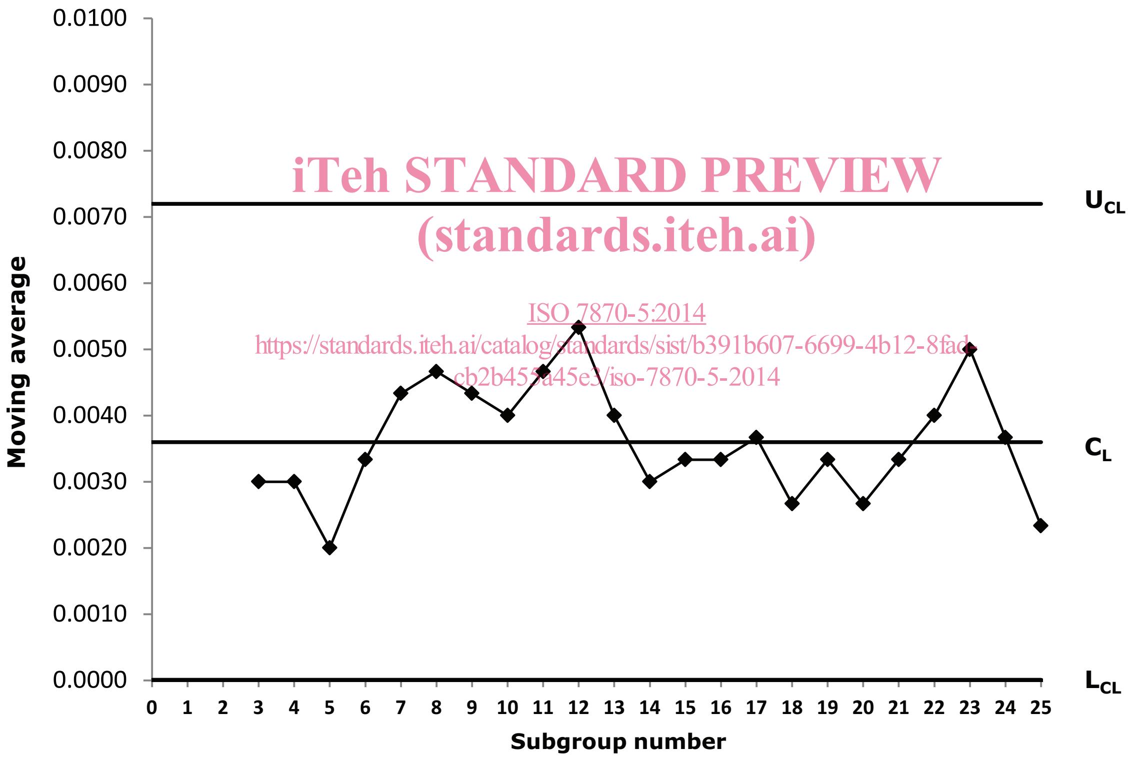
6.5.2 Control limits for moving average control chart

$$C_L = \overline{\overline{x}} = \frac{0{,}0829}{23} = 0{,}0036$$

$$U_{CL} = \overline{\overline{x}} + A_2\overline{R} = 0{,}0036 + 1{,}023 \times 0{,}0035 = 0{,}0072$$

$$L_{CL} = \overline{\overline{x}} - A_2\overline{R} = 0{,}0036 - 1{,}023 \times 0{,}0035 = 0$$

The value of A_2 is taken as 1,023 from Annex A for n = 3. The control chart is plotted in Figure 1.



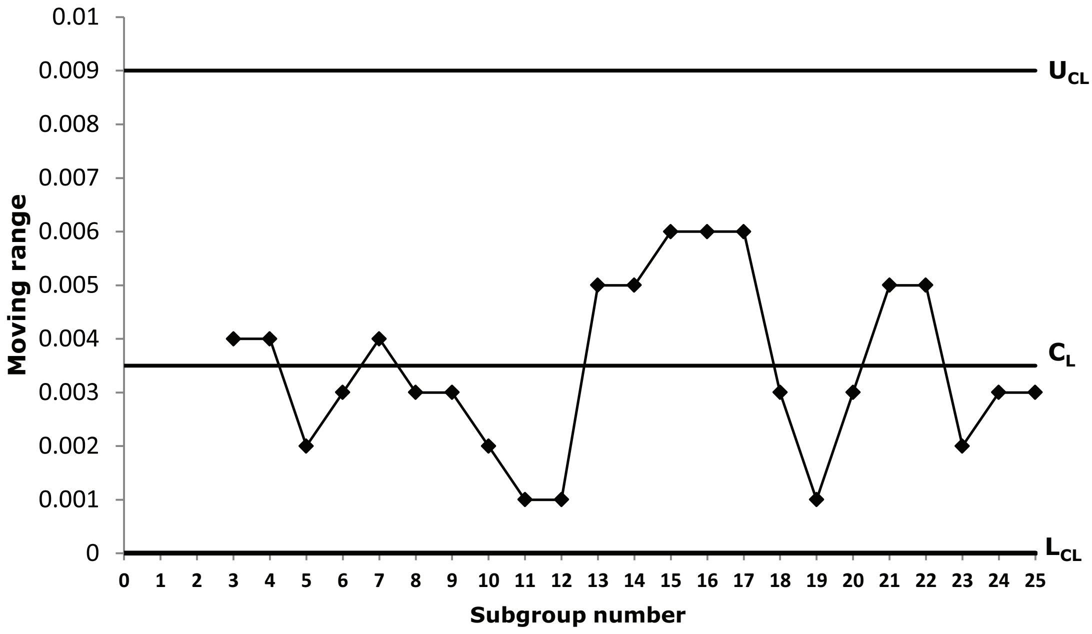


Figure 1 — Moving average and moving range control charts

6.5.3 Interpretation

Process appears to be in state of statistical control.

7 *z*- chart

There are situations where processes are needed to be controlled when there are large varieties of products with different specifications, production runs are small and varying sample/lot sizes. When there are substantial differences in the variance of these products, using the deviation from the process target becomes problematic. There may also be situations when the process does not have a constant target value; instead, the target value keeps on changing with time.

In such cases the commonly used charts like $(\bar{X},R)$ or $(\bar{X},s)$ fail to provide a basis for viewing and validly interpreting control chart and appropriate decision making. A suitable chart to see the pattern and take decisions is the z-chart. The idea is to standardize the data to compensate for the different product parameters in terms of averages and variability and transform each point to a standard normal variate by using the transformation $z=(x-\mu)/\sigma$, provided the expected value of the standard deviation is known at that time point. If process is under control then standard normal variates will lie between +3 and −3. These types of charts are referred to as z-charts.

7.1 Control limits

$$C_L = 0$$

$$U_{CL} = +3$$

$$L_{CL} = -3$$