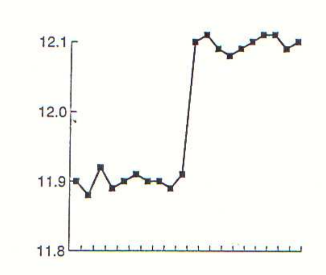
The use of plotting data

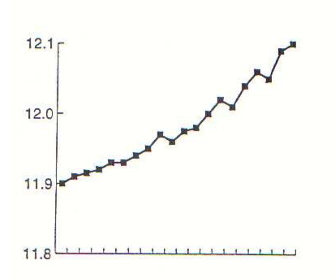
(T. Pyzdek: The Six Sigma Handbook, McGraw-Hill - Quality Publishing, 1999), p. 332

A sample of 100 bottles taken from a filling process has an average of 11.95 ounces, the standard deviation is 0.1 ounce

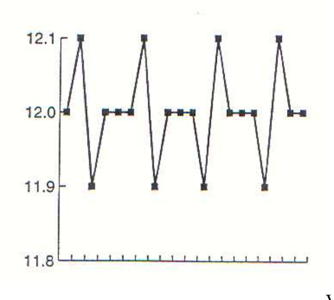
USL=12.1, LSL=11.9

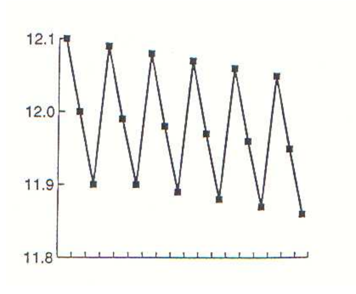
What to do with the process?





(run charts)





When to use X-bar chart

- if subgroups (at similar conditions) may be drawn from the process;
- if large ($\Delta \geq 2\sigma$) deviations are expected, and these are to be detected;
- if small deviations do not cause serious economic consequences;
- if the simplicity of the procedure is a point, but computation of sample mean is feasible;
- the cost of sampling is relatively low.

When not to use X-bar chart

- if subgroups (at similar conditions) may not be drawn from the process;
- if the within-groups fluctuation is much smaller than the between-groups fluctuation, since in this case many outliers were obtained;
- if the deviation to be detected is in the range $0.5\sigma<\Delta<2\sigma$;
- if the cost of sampling/analysis is higher than could be gained by control;
- the process inherently cyclic or it contains trend, in that case the consecutive samples are not independent.

Steps for preparing and applying the X-bar/R chart

- Variable selection : relevant for quality, the measurement should not cost more than omitting the control.
- Deciding on rational subgroups (items produced under essentially the same conditions: the within-subgroup variation should be much less than the fluctuation between subgroups, when possible, consecutive units are used.
- Preliminary estimation of the fluctuation parameter for the process (σ^2) in order to decide the subgroup size; range is used for n<10. The subgroup size is usually 4-6, 5 is typical.

- Phase I: Data collection for estimating process parameters (μ and σ^2), usually 25 subgroups are taken. Plotting the data on charts (location and spread), computation of center line and control limits (trial control limits).
- Deciding on stability (control): If instability occurs, the special causes are found and eliminated. The belonging points are scratched, control limits are recalculated. This procedure is repeated until stability is achieved, additional samples may be drawn if required. This is the end of Phase I.

- On-going control (Phase II) is started if the process is proved to be in control. The analysis is started with the chart of fluctuation (e.g. range) because the control limits of the X-bar chart are valid only for σ=const case. If an outlier occurs, printing error is assumed first (its detection is cheap). The on-going control is to be performed real-time, it has not much sense to discover the necessity of an action for the previous day.

Control chart for individual values

It is not feasible to use averages and ranges:
- the production rate is too slow
- the output is too homogeneous over short time intervals (e.g. concentration of a solution).

Individual value (I or X) chart

Center line and control limits:

$$CL_x = \bar{x}$$

$$MR_i = |x_i - x_{i-1}|$$

(Moving Range)

$$\hat{\sigma} = \frac{\overline{MR}}{d_2}$$

$$\overline{MR} = \frac{\sum_{i=2}^{m} MR_i}{m-1}$$

$$UCL_x = \bar{x} + \frac{3\overline{MR}}{d_2}$$

$$LCL_x = \bar{x} - \frac{3\overline{MR}}{d_2}$$

Moving Range (MR) chart

Center line and control limits:

$$CL_{MR} = \overline{MR}$$

$$UCL_R = \bar{R} + 3\hat{\sigma}_R = \bar{R} + 3\frac{d_3\bar{R}}{d_2} = D_4\bar{R}$$

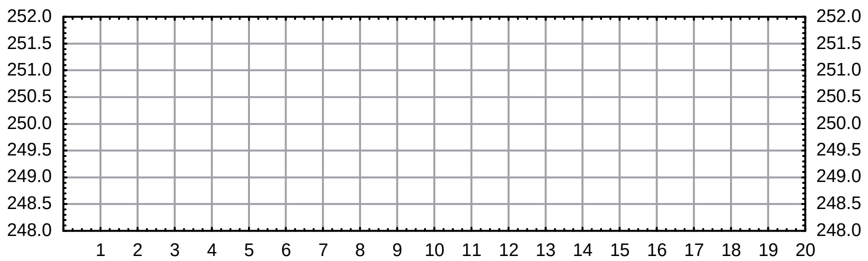
$$UCL_{MR} = D_4\overline{MR}$$

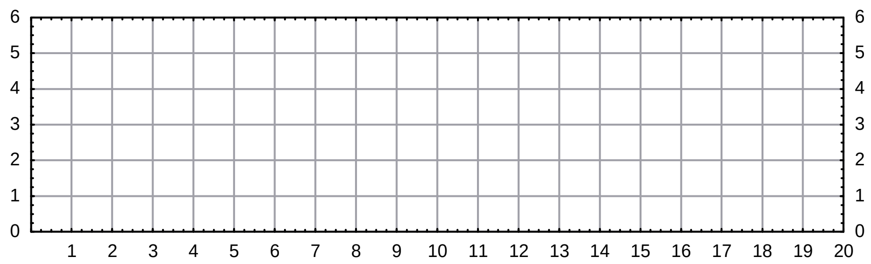
$$LCL_{MR} = D_3\overline{MR}$$

Example 4

Prepare an individual value + moving range chart from the data in the table!

	x_i	$MR_i = \lvert x_i - x_{i-1} \rvert$
1	248.49	-
2	249.84	1.35
3	250.39	
4	249.96	
5	250.08	
6	250.04	
7	250.50	0.46
8	249.95	0.55
9	249.57	0.38
10	250.09	0.52
11	251.86	1.77
12	251.32	0.54
13	250.94	0.38
14	250.63	0.31
15	252.21	1.58
16	250.83	1.38
17	250.61	0.22
18	250.64	0.03
19	250.64	0.00
20	249.88	0.76
average	250.4235	0.5984



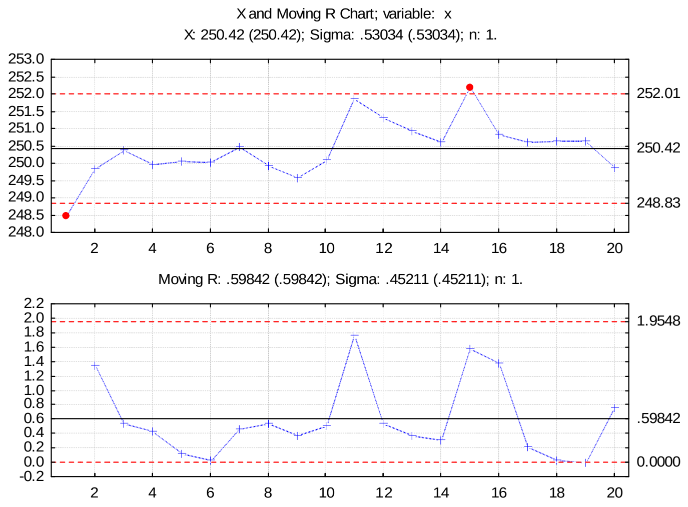


Example 5

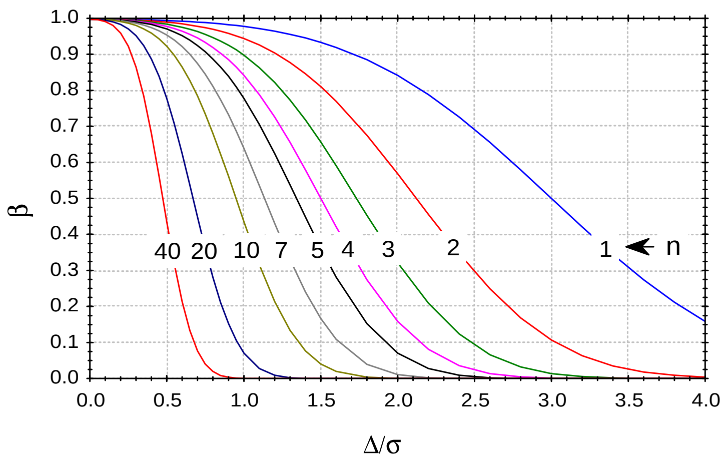
Prepare an individual value + moving range chart from the data in the Indiv1.xls!

Phase I or Phase II?

Statistics>Industrial Statistics>Quality Control Charts
Individuals & moving mange
Variables: X



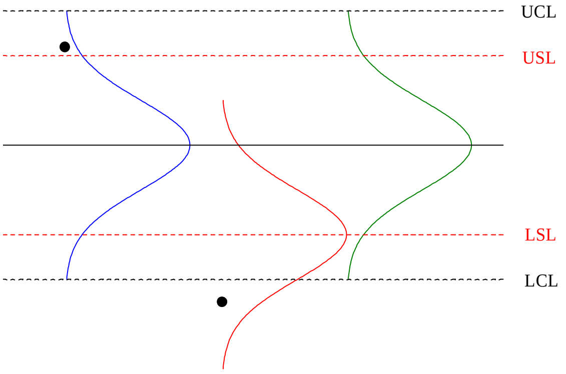
Operating Characteristic (OC) curve for the X-bar chart (α=0.0027)



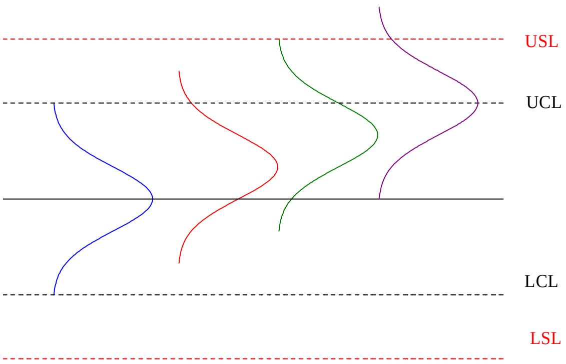
Summary table for the variables control charts

Type of the chart			
$\bar{x}-R$	$\bar{x}-s$	$\bar{x}-s^2$	x–MR
$CL_{\bar{x}} = \bar{\bar{x}}$ $UCL_{\bar{x}} = \bar{\bar{x}} + \frac{3\bar{R}}{d_2\sqrt{n}} = \bar{\bar{x}} + A_2\bar{R}$ $LCL_{\bar{x}} = \bar{\bar{x}} - \frac{3\bar{R}}{d_2\sqrt{n}} = \bar{\bar{x}} - A_2\bar{R}$ $CL_R = \bar{R}$ $UCL_R = \bar{R} + 3\frac{d_3\bar{R}}{d_2} = D_4\bar{R}$ $LCL_R = \bar{R} - 3\frac{d_3\bar{R}}{d_2} = D_3\bar{R}$	$CL_{\bar{x}} = \bar{\bar{x}}$ $UCL_{\bar{x}} = \bar{\bar{x}} + 3\frac{\bar{s}}{c_4\sqrt{n}} = \bar{\bar{x}} + A_3\bar{s}$ $LCL_{\bar{x}} = \bar{\bar{x}} - 3\frac{\bar{s}}{c_4\sqrt{n}} = \bar{\bar{x}} - A_3\bar{s}$ $CL_s = \bar{s}$ $UCL_s = \bar{s} + 3\frac{\bar{s}}{c_4}\sqrt{1-c_4^2} = B_4\bar{s}$ $LCL_s = \bar{s} - 3\frac{\bar{s}}{c_4}\sqrt{1-c_4^2} = B_3\bar{s}$	$CL_{\bar{x}} = \bar{\bar{x}}$ $UCL_{\bar{x}} = \bar{\bar{x}} + 3\frac{\sqrt{\overline{s^2}}}{\sqrt{n}}$ $LCL_{\bar{x}} = \bar{\bar{x}} - 3\frac{\sqrt{\overline{s^2}}}{\sqrt{n}}$ $CL_{s^2} = \overline{s^2}$ $UCL_{s^2} = \frac{\overline{s^2}\chi^2_{fölső}}{\nu}$ $LCL_{s^2} = \frac{\overline{s^2}\chi^2_{alsó}}{\nu}$	$CL_x = \bar{x}$ $UCL_x = \bar{x} + \frac{3\overline{MR}}{d_2}$ $LCL_x = \bar{x} - \frac{3\overline{MR}}{d_2}$ $CL_{MR} = \overline{MR}$ $UCL_{MR} = D_4\overline{MR}$ $LCL_{MR} = D_3\overline{MR}$

Why not the specification limits are used in the chart?



a)



b)

Multiple stream (group) control charts

For multiple-stream processes (e.g., operators, machines, assembly lines); summarising the measurements for all streams simultaneously.

Example 6

An automatic filling machine with 8 heads are used to fill mustard to bottles.

Prepare a control chart for Phase I!

mustard.sta

The samples from the 8 heads are not elements of a single process, they mean 8 different processes

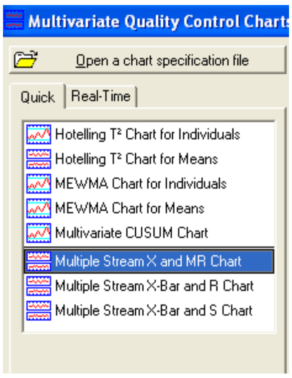
8 I-MR charts

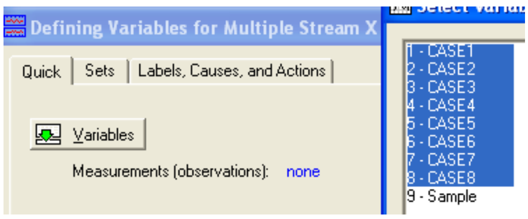
From among the values (means and ranges) the smallest and largest are plotted only.

If these extreme values are within the control limits, the rest are there as well.

sample	HEAD1	HEAD2	HEAD3	HEAD4	HEAD5	HEAD6	HEAD7	HEAD8
1	378	375	367	370	384	372	372	371
2	376	372	362	367	383	373	370	379
3	372	385	373	372	386	380	374	376
4	379	375	370	371	385	380	374	375
5	374	373	362	380	383	372	370	368
6	352	371	366	370	385	371	377	378
7	370	377	370	374	385	380	370	370
8	377	379	367	370	385	372	367	372
9	370	380	367	373	383	369	373	371
10	369	374	366	375	383	370	379	369
11	373	376	374	373	388	372	371	378
12	375	380	371	377	388	368	376	371
13	380	375	374	376	386	380	376	370
14	372	373	375	383	387	378	375	376
15	380	375	370	374	386	368	373	376
16	379	372	373	372	386	378	368	374
17	372	376	369	373	388	381	376	371
18	368	372	372	375	387	380	380	375
19	372	370	370	375	386	379	375	371
20	371	375	383	383	380	379	377	382
21	370	376	380	376	386	374	375	380
22	376	373	368	374	386	370	375	380
23	372	373	372	379	385	381	380	375
24	375	372	369	370	386	372	379	375
25	383	380	369	370	386	375	375	373

Statistics>Industrial Statistics & Six Sigma>Multivariate Quality Control>Multiple Stream X and MR Chart





filling machine with 8 heads