Statistical Process Control

Surveillance in Manufacturing
– vom Statistischen Kontrollieren, Regeln & Lenken –

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Outline

SPC

What does it stand for?

- **S**how **P**rogram for **C**ustomers.
- **S**tatistical **P**olitical **C**orrectness *(Udler/Zaks, Quality Digest, 1997)*.
- Airport Santa Cruz de La Palma (Spain) (*IATA 3-letter code for airports)*.
- **S**cientific **P**rogram **C**ommittee.
- **S**torm **P**rediction **C**enter.
- ...
- **S**tatistical **P**rocess **C**ontrol = ?

SPC synonyms?!

- Change point detection.
- On-line monitoring.
- Surveillance ... Überwachung.
- Control charting ... Kontrollkarten.
- Continuous inspection.
- Disorder problems.
- Detection of abrupt changes.
- Jump detection.
- Fault detection (... FDC).
- ...

Some historical background

- WALTER A. SHEWHART
  (1891-1967, Ph.D. in physics, Western Electric, Bell Labs)
  p and $\bar{X}$ control chart (1924/31)
- W. EDWARDS DEMING
  (1900-1993, Ph.D. mathematics/mathematical physics)
  "14 points for management", Deming's wheel (PDCA/PDSA), late 1940s-1965 in Japan
- JOSEPH M. JURAN
  (1904-2008, B.S. in electrical engineering)
  Pareto principle, late 1940s in Japan
- JAMES M. LUCAS
  (DuPont, now JM Lucas & Associates)
  application of CUSUM at DuPont in 1970/80s

SPC jargon

Shewhart

- Two kinds of variation:
  - Common cause (chance cause): non-removable, inherent, could be described in terms of prob. theory.
  - Special cause (assignable cause): hopefully removable, in some way unanticipated (and unpredictable), should be detected as fast as possible, "significant enough" that it can be detected.
- "In statistical control":
  Due to Shewhart, a process is called *in statistical control*, if it features only common cause variation.

1 Scope

Statistical process control (SPC) concerns the use of statistical techniques and/or stochastic control algorithms to achieve one or more of the following objectives:

a) to increase knowledge about a process;

b) to steer a process to behave in the desired way;

c) to reduce variation of final-product parameters, or in other ways improve performance of a process.

"Seven Tools of SPC" or "The Magnificent Seven"

e. g., Montgomery (2001)

- Histograms
- Check Sheets (tally sheet)
- Pareto Charts (80:20)
- Cause and Effect Diagrams (Ishikawa, fishbone)
- Defect Concentration Diagrams
- Scatter Diagrams
- Control Charts

One of the "old boys"

Wheeler (1997),
A discussion on statistically-based process monitoring and control. Individual contributions.
Journal of Quality Technology, 29, 154-155.

And while it is true that a control chart can be used for process monitoring, the point is that monitoring is only a *minor* part of what control charts can do, rather than being *all* that they can do.

...
With a minimum of computation and effort they allow the human mind to immediately focus on the interesting characteristics in the data without being distracted by the unimportant details.

SPC conceptions

European voices

- WETHERILL/BROWN (1991/5)

  On-line SPC methods ↘ preventive SPC methods: *... we inspect the process, and try to use process control to avoid defective items being produced.*

- RINNE/MITTAG (1995)

  Fertigungsüberwachung ↘ Qualitätsregelkarten: *... permanent zu prüfen, ob ein Fertigungsprozeß unter statistischer Kontrolle verläuft.*

- STORM (2007)

  Aufgaben der statistischen Prozeßkontrolle sind die *laufende Überwachung der Produktion* an Hand von – dem Prozeß in gewissen Abstand entnommenen – Stichproben und ihrer Beurteilung und die *Verhütung von Ausschuß* durch rechtzeitiges Eingreifen in den Fertigungsprozeß.

My favorite

WOODALL/MONTGOMERY (1999),
Research issues and ideas in statistical process control.
Journal of Quality Technology, 31, 376-386

... in the area of control charting and SPC. As a general definition, we include in this area any statistical method designed to detect changes in a process over time.

- SMYTH-RENSHAW (2009), "Who stole SPC?", ENBIS9 in Göteborg,
- STARK (2007), "Praxis widerlegt Theorie", QZ 52,
- WOODALL (2000), "Controversies and Contradictions in Statistical Process Control", JQT 32,
- CROWDER, HAWKINS, REYNOLDS JR., YASHCHIN (1997): *"There are few areas of statistical application with a wider gap between methodological development and application than is seen in SPC."*, JQT 29, No. 2 – the whole issue is discussion about SPC.
- HOYER & ELLIS (1996), "A Graphical Exploration of SPC", Quality Progress, May 65-73, June 57-64, November 85-93.

SPC on the shopfloor

anecdotic notes from my industry times

- “SPC – this is about these sophisticated runs rule as ‘2 of 3’!”,
- “My SPC is out of SPEC”,
- “Oh, this alarm stems from a mask that does not belong to this chart”,
- “Why should I apply $3\,\sigma$ limits despite I do not know what to do after an alarm?”,
- “Control charts should be handled exclusively by the cleanroom personnel.”
- ...

SPC issues – in daily practice

Infrastructure

- Again, different perceptions of SPC.
- Poor education in statistics of physicists and engineers – SPC is part of curriculum at some economics/business administration and mechanical engineering departments.
- There is no powerful SPC software on the market.
- Excel is the predominant analysis tool. Some use MatLab, Mathematica, JMP or Design Expert.
- Auditing companies and quality department.
- IT vs. data customers.
- Discipline, Controlling and Priorities.

SPC issues – in daily practice

Data

- Normal is not normal. It is, however, a more suitable distribution model than expected from pessimistic “model converts”.
- Variance components.
- Varying batch sizes.
- Control vs. monitor (EPC and SPC).
- Large data sets (so-called trace data: 100 parameters, every second appears a new value, processes last between 5 minutes and several hours).
- Choice of the in-control model – e. g., small drifts are not bad.
- Number of control charts (thousands ... millions).

SPC issues in general

- Confusion of specification and control limits (more limits types: Wheeler's action limits, reasonable limits, ...)
- Confusion of drift and shift.
- Outliers and the battle between Shewhart and "modern" control charts.
- SPC as reporting tool within the company and to customers (C_{pk} etc.).
- How do I measure the success (weekly, monthly) of SPC?
- The software.

Wrap-up

There are at least 2 perceptions/conceptions of Statistical Process Control:

- The holistic approach covering nearly all statistical methods that are used in industry.
- Monitoring.

Here: Monitoring.

SPC = Surveillance = Control Charting = Fault Detection.

The SPC framework

a recipe

Imagine that you are a process owner who should apply SPC to his/her process. Then you should

- identify existing and potential data that may characterize your process – it should be data which is regularly collected.
- differentiate between product, tool, facility and material data.
- deploy process understanding and exploratory data analysis (EDA).
- pick a suitable (what is in-control?) data model and control chart.
- enable the data collection, processing, and transfer.
- install alarm rules, logging, and reporting.
- introduce an appropriate reviewing process.

The SPC framework

kind of a definition

1. SPC in the narrow sense:

   Collection of statistical methods for detecting changes.

2. SPC in the wider sense:

   Fusion of 1, data processing, EDA, and intelligent reporting.

Control charts – Kontrollkarten

Definition

Graphical device for presenting observed data vs. observation time (subgroup number) which allows to judge the process stability in a sequential manner.

Traditions, Properties, Features etc.:

- plot the observations themselves or appropriate transformations ($\bar{X}$, S^2, S, $\ln S^2$, R, Z, ...)
- line or/and scatter plot,
- constant (sometimes curved) control limits (alarm thresholds); crossing indicates a process change which ought to be presumed as reason for action, that is, there is some evidence that the process became unstable.

Control charts – Kontrollkarten

Types, Classes, ...

- One- or two-sided,
- univariate, multivariate, simultaneous,
- monitoring the mean, scale (variance), higher moments, (auto)correlation coefficients, any other parameter, profiles,
- take statistics like sample average, median, standard deviation, range, distances,
- Shewhart w/ and w/o runs rules, CUSUM, EWMA, Shiryaev-Roberts, Bayesian schemes, ...,
- data is normally, χ^2, exponentially, Poisson, binomial, ... distributed,
- independent, correlated, GARCH type data.

Control Charts History

1. $p, \bar{X}$ control chart designed by Shewhart (1924/31).
2. Bayesian approach by Girshick/Rubin (1952).
3. CUSUM by Page (1954).
4. Runs Rules
   (Page 1955, Western Electric **1956**, Roberts 1958, Nelson 1984).
5. EWMA (GMA) by Roberts (1959).

Modeling of a stochastic process with a possible distributional change

Sequence of random variables $X_1, X_2, \ldots$ with cdf $\{F_{(i)}\}$ and a certain (unknown) time point $\tau =$ change-point with

$$F_{(i)} = \begin{cases} F_0 & , \; i < \tau \\ F_1 & , \; i \geq \tau \end{cases} .$$

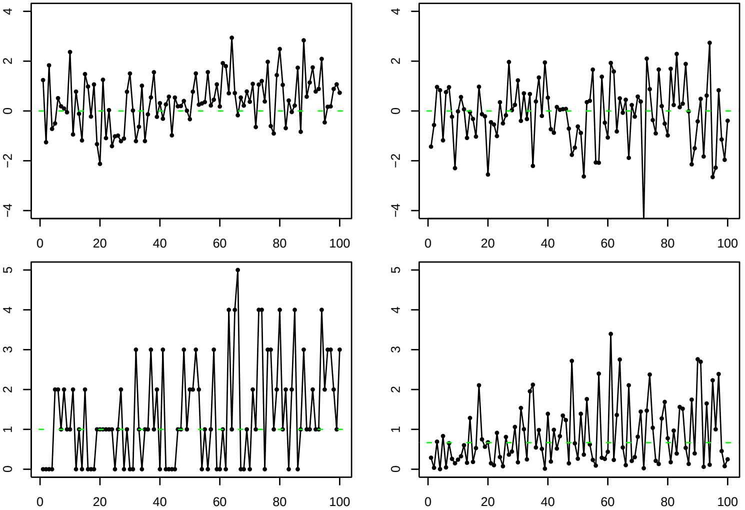
Example: $F_0 = \mathcal{N}(\mu_0, 1)\,,\; F_1 = \mathcal{N}(\mu_1, 1)$ + independence

Notation: $\{X_i\}_{i=1}^{\tau-1}$ – process in control,

$\{X_i\}_{i=\tau}^{\infty}$ – process out of control.

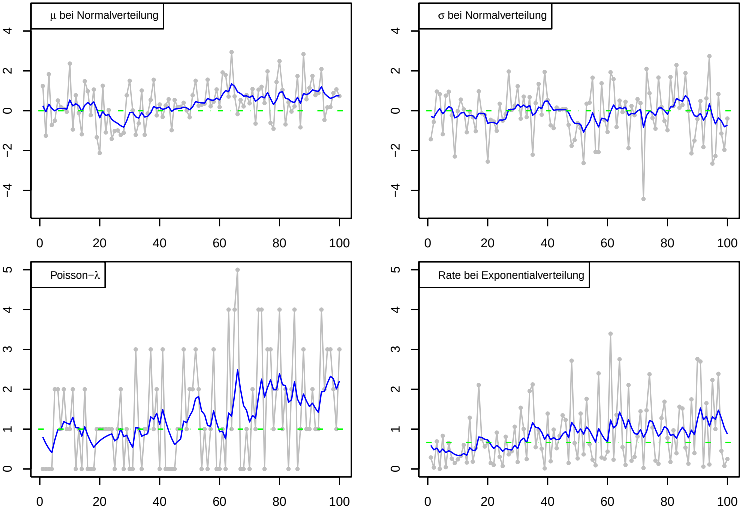
Process with change-point

artificial data



Process with change-point

artificial data



Control Charts

presentation of typical ones

- Done for the standard model:

$$X_i \sim \mathcal{N}(\mu(i), 1)\,,\ i = 1, 2, \ldots$$

$$\mu(i) = \begin{cases} \mu_0 = 0 & , \ i < \tau \\ \mu_1 \neq 0 & , \ i \geq \tau \end{cases}$$

- Characterize the chart via it's stopping rule.
- Shewhart's $\bar{X}$ chart.
- ... plus runs rules.
- EWMA.
- CUSUM.

Shewhart's $\bar{X}$ chart

SHEWHART 1931.

$$
\begin{aligned}
L &= \inf\{i \in \mathbb{N} : |X_i| > 3\}\,, \\
&= \inf\{i \in \mathbb{N} : |X_i - \mu_0| > 3\sigma\}\,,
\end{aligned}
$$

"Flag as soon as the first observation is sufficiently far from target."

Remarks:

- Most simple and popular one.
- Straightforward: One-sided, $S/R/S^2$, p, T^2, ...
- Deploys only recent data:

  (i) less sensitive for small changes,
  (ii) allows exception alibi.

Runs Rules

PAGE 1955, Western Electric 1956, ROBERTS 1958, NELSON 1984.

Flag if

- (Shewhart limits) $|X_i - \mu_0| > 3\sigma$,
- (2 of 3) 2 of 3 succeeding X_i are $\begin{cases} > \mu_0 + 2\sigma \\ < \mu_0 - 2\sigma \end{cases}$,
- (4 of 5) 4 of 5 succeeding X_i are $\begin{cases} > \mu_0 + \sigma \\ < \mu_0 - \sigma \end{cases}$,
- (8 of 8) 8 of 8 succeeding X_i are $\begin{cases} > \mu_0 \\ < \mu_0 \end{cases}$.
- ...

DIVOKY & TAYLOR (1995) studied 613 different trend rules.

EWMA
Exponentially Weighted Moving Average

Roberts 1959.

$$\begin{aligned} Z_0 &= z_0 = \mu_0 = 0\,, \\ Z_i &= (1-\lambda)Z_{i-1} + \lambda X_i\,,\; i = 1, 2, \ldots\,,\; \lambda \in (0,1]\,, \\ &= (1-\lambda)^i z_0 + \lambda \sum_{j=1}^{i} (1-\lambda)^{i-j} X_j\,, \end{aligned}$$

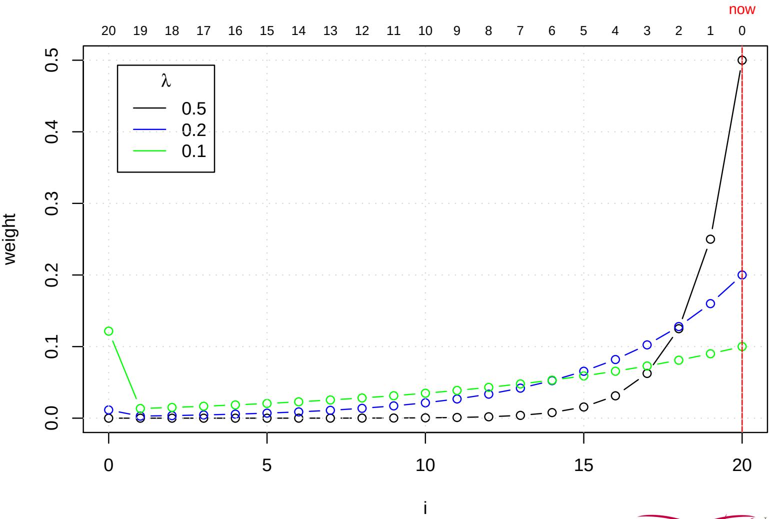
$$E(Z_i) = \begin{cases} \mu_0 & , i < \tau \\ (1-\lambda)^{i-\tau+1}\mu_0 + \left(1 - (1-\lambda)^{i-\tau+1}\right)\mu_1 & , i \geq \tau \end{cases},$$

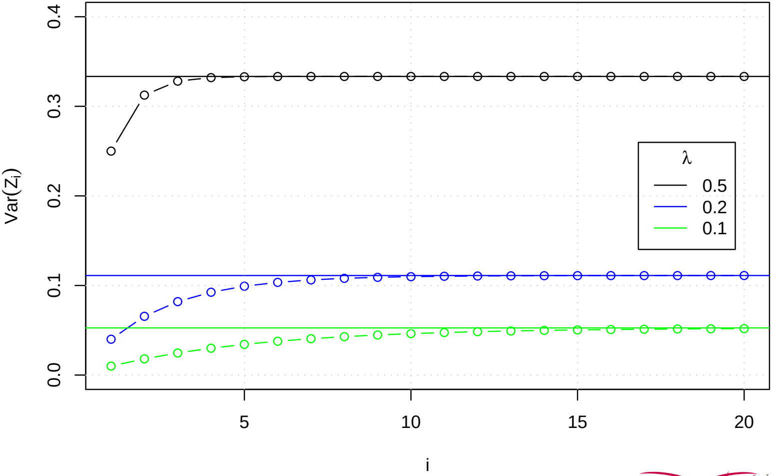
$$Var(Z_i) = \frac{\lambda}{2-\lambda}\left(1 - (1-\lambda)^{2i}\right)\sigma^2 \;\rightarrow\; \frac{\lambda}{2-\lambda}\sigma^2 \quad for \quad i \rightarrow \infty\,.$$

$$L = \inf\left\{ i \in \mathbb{N} : |Z_i - \mu_0| > c\sqrt{\frac{\lambda}{2-\lambda}}\sigma \right\}.$$

EWMA

Weight expansion




0.0
0.1
0.2
0.3
0.4
Var(Zi)
5
10
15
20
i
λ
0.5
0.2
0.1

- ROBERTS (1966): “This type of test, along with a simple graphical procedure for locating the point representing Z_i on a $\bar{X}$ control chart, was suggested by J. W. Tukey to the present author ...”
- EWMA smoothing is popular in time series analysis, finance, process control (!!), ...
- Rule of thumb for choosing λ: The smaller the shift to detect, the smaller λ. Popular choices are $\lambda = 0.1$ and $\lambda = 0.2$. $\lambda = 1 \rightarrow$ Shewhart chart.
- Straightforward: One-sided, $S/R/S^2$, p, T^2, ...
- Setup of c: quick and dirty $c = 3$.

CUSUM
Cumulative Sum

Page 1954.

$$
\begin{aligned}
Z_0 &= z_0 = \mu_0 = 0\,, \\
Z_i &= \max\{0, Z_{i-1} + X_i - k\}\,,\; k = (\mu_0 + \mu_1)/2\,, \\
L &= \inf\left\{i \in \mathbb{N} : Z_i > h\sigma\right\}\,.
\end{aligned}
$$

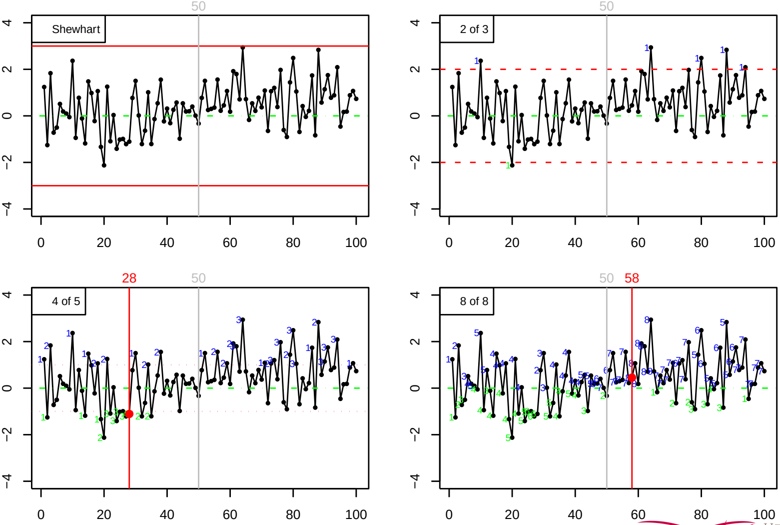
two-sided:

$$
\begin{aligned}
Z_0^{\pm} &= 0\,, \\
Z_i^{\pm} &= \max\{0, Z_{i-1}^{\pm} \pm k\}\,, \\
L &= \min\left\{i \in \mathbb{N} : \max\{Z_i^+, Z_i^-\} > h\sigma\right\}\,.
\end{aligned}
$$

- Original setup is one-sided.
- It looks more artificial than EWMA and Shewhart (and runs rules).
- It is connected to the SPRT (sequential probability ratio test). Based on the SPRT the CUSUM scheme could be developed also for non-normal models.
- It is worst-case optimal (MOUSTAKIDES 1986).
- k is set via the choice of μ_1.
- h is more subtle – software can assist.

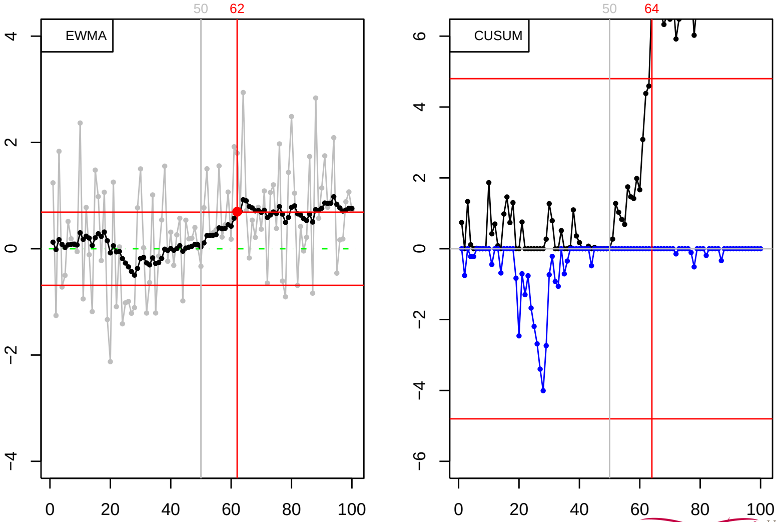
Comparison

Shewhart and Runs Rules



Comparison

EWMA and CUSUM



How to choose the right one?

- Simplicity $\Rightarrow$ Shewhart (beware of the exception alibi).
- Performance $\rightsquigarrow$ How to measure?
- Further: Ease of setup, look and feel, software.

Measuring control chart performance

history

1. Shewhart (192x,193x) similar to tests: error probabilities,
2. Aroian/Levene (1950) average spacing number and average efficiency number,
3. Girshick/Rubin (1952) Bayesian framework,
4. Page (1954) introduced term ARL *as the average number of articles inspected between to successive occasions when rectifying action is taken.*
5. Barnard (1959) *If it were thought worthwile one could use methods analogous to these given by Page (1954) and estimate the average run length as a function of the departure from the target value. However, as I have already indicated, such computations could be regarded as having the function merely of avoiding unemployment amongst mathematicians.*

Measuring control chart performance

Average Run Length (ARL)

Notation: $E_\tau(.)$ expectation for given change-point τ.

Definition:

$$ARL = \begin{cases} E_\infty(L) & \text{, process in control} \\ E_1(L) & \text{, process out of control} \end{cases} .$$

Note that for dealing with the ARL, the sequence $\{X_i\}$ is (strong) stationary with the same probability law for all i.

Measuring control chart performance

history II

❻ Shiryaev (1961/3) random change-point model

$$P(T=\tau) = \begin{cases} \pi & , \ \tau = 0 \\ (1-\pi)\,(1-p)^{\tau-1} p & , \ \tau > 0 \end{cases} \ , \ \pi \in [0,1)\,,\ p \in (0,1)$$

and minimize

$$\begin{cases} P_{\pi,p}(L < T) + c\, E_{\pi,p}(L-T)^+ & \text{for all s. t. } L \\ E_{\pi,p}(L - T \mid L \geq T) & \text{for all s. t. } L \text{ with } P_{\pi,p}(L<T) \leq \alpha \end{cases}$$

❼ Roberts (1966) $\mathcal{D} := \lim_{\tau\to\infty} E_\tau\big(L - \tau + 1 \mid L \geq \tau\big)$
("steady-state ARL", R. "replaced" ∞ by 9)

❽ Lorden (1971) $\mathcal{W} := \sup_{\tau \geq 1} \operatorname{ess\,sup} E_\tau\big((L-\tau+1)^+ \mid \mathcal{F}_{\tau-1}\big)$

❾ Pollak/Siegmund (1975) $\mathcal{D}_{\text{PS}} := \sup_{\tau\geq 1} E_\tau\big(L-\tau+1 \mid L \geq \tau\big)$

Measuring control chart performance

Anyway, the ARL is the dominating measure!

Possible reasons:

- **Shewhart chart**

  $\mathcal{W} = \mathcal{D} = \mathcal{D}_{\text{PS}} = \mathcal{L} = E_1(L) = E_\tau(L - \tau + 1 \mid L \geq \tau)$.

- **CUSUM**

  $\mathcal{W} = \mathcal{D}_{\text{PS}} = \mathcal{L}$,

  modifications: $\mathcal{D} = \mathcal{D}_{\text{PS}} \neq \mathcal{L}$.

But:

- **EWMA**

  All measures provide different values.

- ...

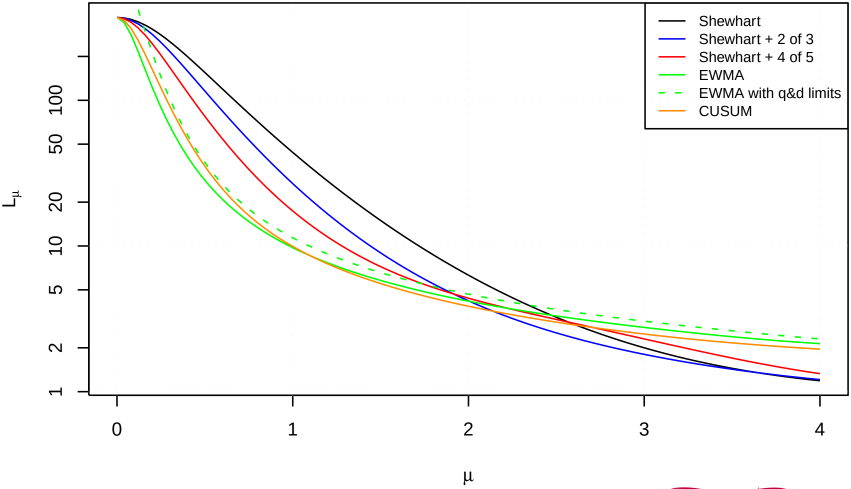
ARL

Calculation!?

- Numerical methods have been available since 197x.
- Implemented in a few statistics packages only: SAS, ..., R.
- For Shewhart chart, L has a geometric distribution.
- For EWMA, deploy the mentioned quick & dirty approach, that is, take the same factor as for Shewhart ($c = 3$).
- Shewhart with $c = 3 \rightsquigarrow E_\infty(L) = 370.4$.
- Denote now $\mathcal{L}_\mu$ the ARL for given mean μ.

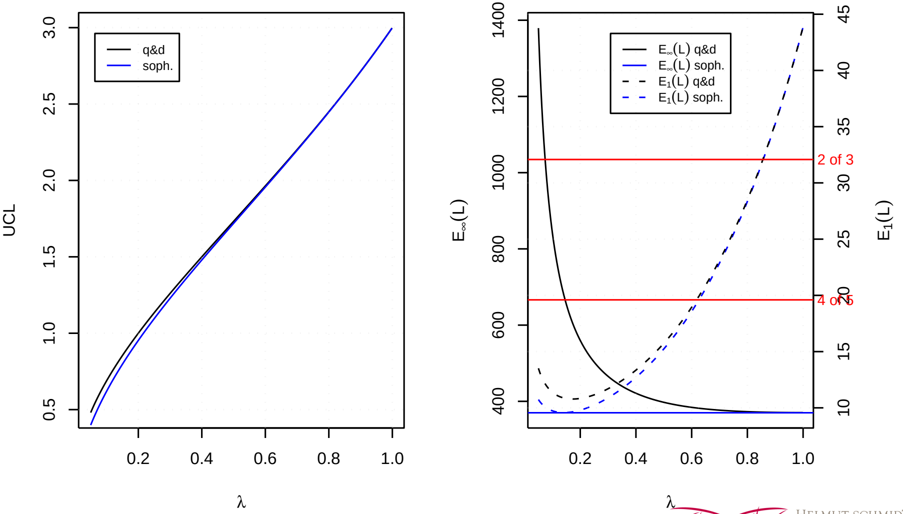
Comparison

ARL profiles



EWMA ARL

Sophisticated vs. quick & dirty



If not the normal mean?

(I) not mean

- Next candidate would be the scale (variance or standard deviation) for normal variates.
- Distinguish two data collection designs (variance types) –
  (i) collect batches and monitor the within-batch variation,
  (ii) monitor the variation between batches or single observations.

Normal variance

(i) within batches

- Collect batches with $n \geq 2$ data points,
- apply an appropriate variance estimator:
  - sample variance S^2,
  - sample standard deviation S,
  - sample range R,
  - other transformations of S^2,
- deploy Shewhart, EWMA, or CUSUM charts. For setting up the limits use
  - the quantiles of the above statistics (simple),
  - rough approximations for EWMA as for the mean case,
  - formulas given in certain papers,
  - R library `spc` for EWMA,
  - Hawkins' `anyarl.exe` for CUSUM (see the book by Hawkins and Olwell).

Normal variance

(ii) between batches

- Calculate batch mean (if needed),
- monitor it's square with Shewhart, EWMA or CUSUM,
- or construct the *MR* (moving range) chart: Calculate $MR_i = |\bar{X}_i - \bar{X}_{i-1}|$ and apply your favorite chart to MR_i. Consider the special correlation structure of $\{MR_i\}$.
- It is less investigated than situation (i).

Monitoring normal variance

Short summary

- 2nd popular parameter with large gap to the mean,
- in SPC software dominate R, S, MR Shewhart charts,
- some papers on monitoring variance components,
- some more papers on simultaneous monitoring mean and variance,
- S^2 charts look similar to some multivariate charts based on distances.

What else?

other parameters of normally distributed data

- correlation structure or
- normal becomes non-normal (skewness, kurtosis)
- ... this is more an academic interlude.

What else?

other parameters and other distributions

- Count something (failures, successes): binomial (*p* or *np* chart) or Poisson distribution (*c* or *u* chart).
- In SPC software typically the Shewhart charts are present. There are several papers on EWMA and CUSUM for counts.
- It is reasonable to consider instead of the counts the time (geometric and exponential, respectively) between failures etc.
- Sometimes a normal approximation works well.

Drift instead of shift

the unknown competing change point design

- In Statistics usually the shift is modelled.
- Often shift and drift are confused.
- Drift model fits to creeping changes (tool wear).
- There are certain runs rules to detect drift quickly.
- Statistical analysis started in the 1980ies.
- Standard drift model is trend linear in observation number.
- There are some very special control charts for drift.

Drift monitoring

some practical remarks

- Shift control charts detect reasonably quick drift.
- The popular trend runs rules are useless.
- The sophisticated special drift charts are not worth the effort.
- The naïve approach (monitor the differences) does not work well.
- Clarification needed whether the drift itself is the target or the increasing mean (beyond a critical level)!
- Nonlinear trends and non-equidistant data series have to be studied.
- Some useful functions are in the R library spc.

Assumption next to normality

that might be violated

is the independence.

- Alwan (1989) analyzed in his PhD thesis 235 data sets used within SPC literature: In about 85 % the control limits were misplaced. In nearly half of these cases neglected autocorrelation was responsible.
- It was already discussed in the 1960ies and 1970ies.
- Two basic approaches to deal with it: (i) Identify an appropriate time series model and monitor the residuals. (ii) Tune (only) the limits. For practice (i) is appealing.
- Mostly an AR(1) model is sufficient.
- Recently, integer time series models became popular in literature.
- There are many papers.

Multivariate SPC

Nearly as old as univariate SPC

- In the majority of cases, it is multinormal.
- Several concepts. Typically, a distance is measured or a projection is done, to reach a univariate statistic.
- It started in 1947 with Hotelling. His T^2 is the extension of the t distribution to a multivariate world. Eventually, a Shewhart type control chart was constructed.
- Nowadays, there are a lot of different charts (incl. MEWMA, MCUSUM).
- Some SPC software may offer assistance in dealing with multivariate SPC, but usually it has to be incorporated in the data pre-processing.
- One issue is less frequently discussed: Could there be several change points? That is, first X_1 changes, later X_2 ...
- One-sided setups are not straightforwardly realized.

Monitoring profiles

next after multivariate

Idea: The "nice" process is characterized by a certain functional relationship, such as between response and one or more explanatory variables.

Keywords: Functional Data Analysis, PCA, wavelets, PLS

- Create golden profile.
- Reduce dimensionality by parametric models or above methods.
- Identify "allowed" variation.
- Good introduction: WOODALL, SPITZNER, MONTGOMERY, GUPTA (2004) Using Control Charts to Monitor Process and Product Quality Profiles, *Journal of Quality Technology* **36**, *309-320.*

Non-parametric control charts

to get rid of distributional assumptions

- Correct formulation: distribution-free control charts.
- Essentially, based on the ranks of the data.
- Up to now, mostly developed and investigated in the fashion of Shewhart charts.
- Compared to their parametric counterparts they perform reasonably well (up to 90%, and more, effectivity).
- Not part of SPC software packages.

Control chart design

and the impact of estimated parameters

- Typically, SPC-Statisticians assume that the involved parameters are known.
- Essentially started in the 1990ies, a couple of papers were published on the impact of estimation uncertainty to the control chart performance.
- Typically, the ARL or quantiles of the RL-distribution are treated as random variables due to their connection to the estimation process during pre-run.

Further patterns in SPC

An incomplete list

- Variable sampling intervals – tune the collection pattern.
- Variable chart constants (λ, k, alarm thresholds, ..., GEWMA).
- Unknown out-of-control parameter – GLR charts.
- Bayesian charts.
- Fast initial response.
- Different performance measures.
- Intelligent scoring.
- Economic design of control charts.
- Combining SPC and EPC.
- Classification after signal.
- Study misleading signals in simultaneous schemes.
- Inertial properties of control charts (worst-case behavior).

SPC software

my wish list

Properties of a “reasonable” SPC software:

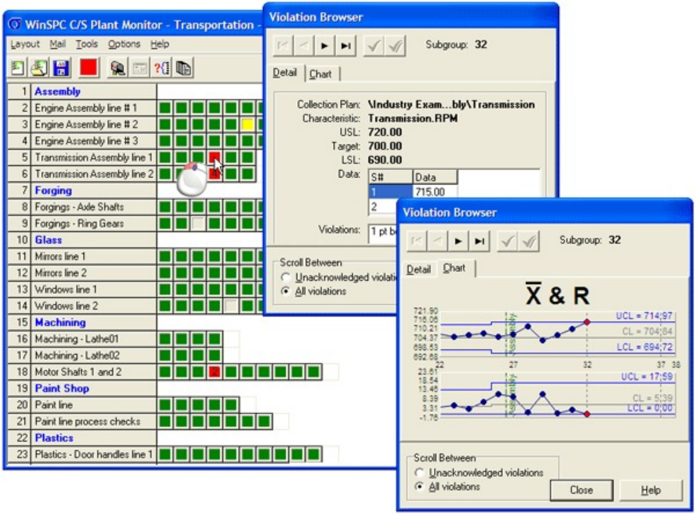
- powerful data base,
- fast interface that could be easily configured and deployed,
- rich assortment of alarm functions (e-mail, Pager, SMS, Pop-ups, ...),
- traceability,
- it should be simple to add annotation to control charts,
- intuitive usability,
- multivariate models included,
- more EWMA and friends (less 4 of 5),
- extendable possibilities of report creation,
- ...

SPC software

examples from semiconductor

company	product (creator)	
AMTC	WinSPC (DataNet)	http://www.winspc.com
AMD (now GlobalFoundries)	ASPECT (own product)	...
Infineon	SPACE (Camline)	http://www.camline.com

WinSPC: Plant Monitor



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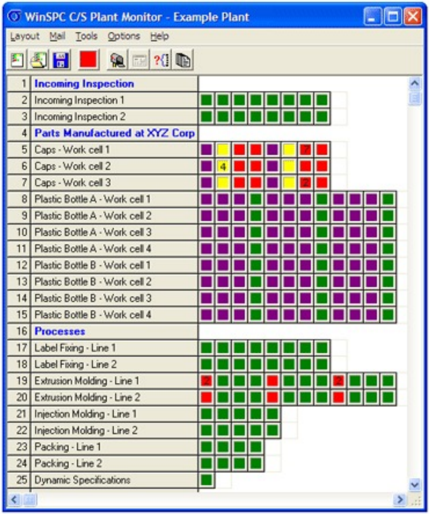
WinSPC: alarm types

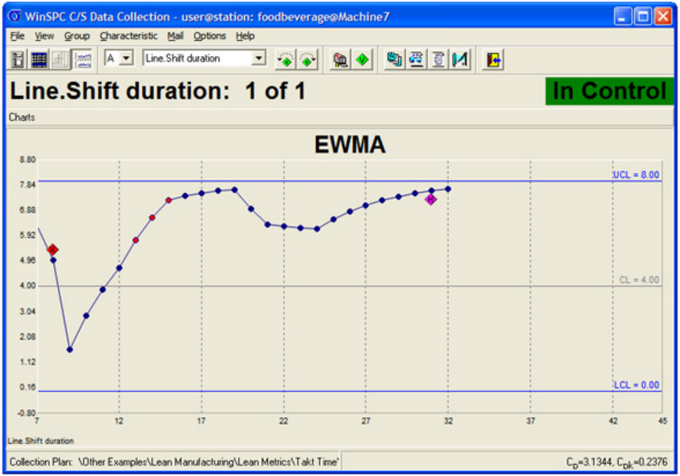


Colors typically denote the following:

- In Control Condition or Custom
- Out Of Control Condition or Custom
- Trending Violation or Custom
- Mixture/Stratification or Custom

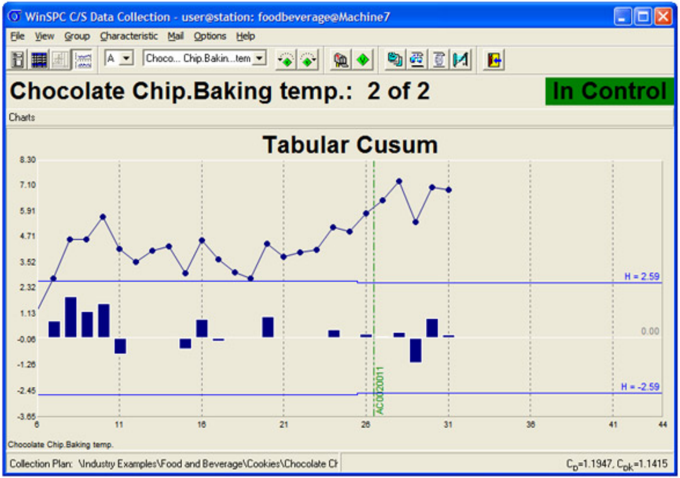
Numbers indicate how many unacknowledged occurrences currently exist.

WinSPC: EWMA



WinSPC C/S Data Collection - user@station: foodbeverage@Machine7
File View Group Characteristic Mail Options Help
Line.Shift duration
Line.Shift duration: 1 of 1
In Control
Charts
EWMA
8.80
7.84
6.88
5.92
4.96
4.00
3.04
2.08
1.12
0.16
-0.80
UCL = 8.00
CL = 4.00
LCL = 0.00
7
12
17
22
27
32
37
42
45
Line.Shift duration
Collection Plan: \Other Examples\Lean Manufacturing\Lean Metrics\Takt Time'
Cp=3.1344, Cpk=0.2376

WinSPC: CUSUM



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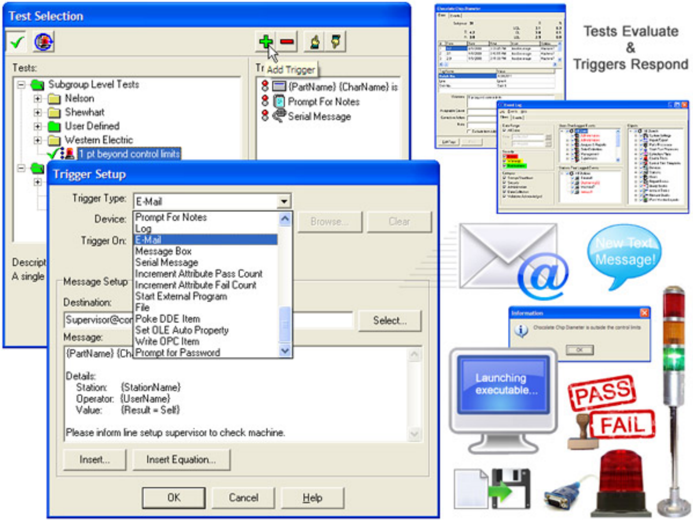
WinSPC: config trigger



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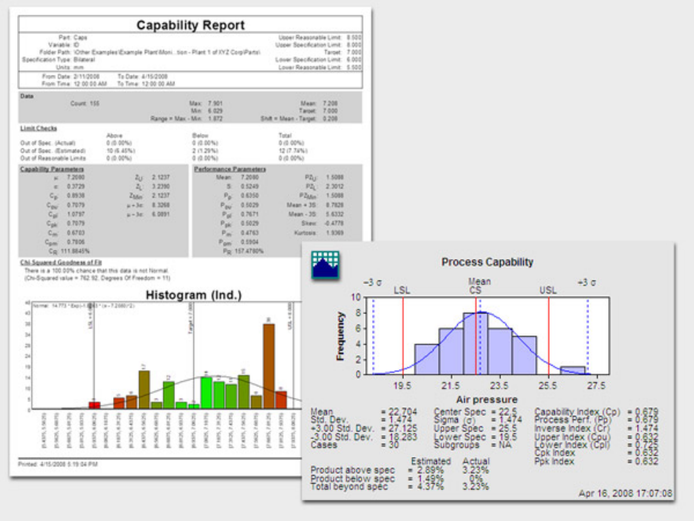
WinSPC: capability report



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SPC software

general remarks

- Hundreds of statistics software packages, a couple of them claim to cover also SPC: typically EDA (and retrospective analysis) could be done and charts could be designed, but not more.
- Dozens of SPC software packages that provide sufficient data transfer capabilities, reporting stuff and nice GUIs, but they lack, usually, of modern control charts (they offer Shewhart charts with and without runs rules).
- $\Rightarrow$ write your own piece of software.

Conclusions

- Despite it's long history (over 80 years) SPC is not a mature technology.
- Many papers, software packages, training courses, standards etc. and we are at the beginning.
- Debate is ongoing – see introduction.
- New application areas (health care and finance) are very promising and might help to straighten things.