

A coloured version of the J-chart or the amc-D J-Chart

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I still have the 1973 newspaper cutting¹ from which I learned about the mysteries of the “CuSum Plot”! The CuSum Plot was invented at ICI in the 1950s to improve the interpretation of process control charts, which were also quite a recent innovation. I became very keen on it and even managed to get it incorporated into the software of the Oxford QN NIR analyser² in 1987. I wrote about CuSum charts in one of the early predecessors of this column³ but now it is time to move on! In March of this year the Analytical Methods Committee (AMC) of the Royal Society of Chemistry published⁴ a technical brief outlining the use of the J-chart or (zone control chart) as an alternative to CuSum charts. The AMC has an excellent reputation so I am quite prepared to accept their advice. However, when I read it I decided that it could be improved by the addition of colour and as the plot is most likely to be used as a computer graphic, there would be no difficulty in generating coloured plots. This article explains the J-chart and introduces my coloured modification.

Process control charts

We hope that spectroscopic measurements are being used, with increasing frequency, to provide the analytical data

to control processes. If this data is being used to control a process, either manually or automatically, then it needs to be plotted so that the supervisor can be assured that all is well (or take action). The original method for doing this was with a “Shewart” chart. An example is shown in Figure 1. Essentially the chart has three horizontal lines, a lower control limit, a central line and an upper control limit. In order to use the chart you need to know the average value (av) of the measured analyte and its standard deviation (sd). The control limits are normally set at values of $av - 3sd$ and $av + 3sd$. Results are plotted from left to right in terms of sample number or time. The idea is that while results fall within the control limits the process is under control and should not be changed but if a result falls below the lower control limit or above the upper control limit then corrective action should be taken. Sometimes warning limits are also shown at $\pm 2sd$ and there are then rules as to how many consecutive results can be above these warning limits. CuSum charts⁵ were introduced to overcome the control chart's lack of sensitivity to small shifts of the mean value and reduce the sensitivity to outlier (wild) results. However, even I have to admit that CuSum charts are more complex to explain and some people find them conceptually challenging. Time to look at the “new” idea: zone control charts.

Zone control (J-)charts

The idea behind the zone control chart^{6,7} is an attempt to combine the best features of control and CuSum charts. The model chart looks similar to the Shewart chart but with lines marking av and $\pm 1, 2$ and $3sd$, Figure 2. A cumulative sum is also calculated according to rules. If an observation falls within the area between the $av - sd$ and $av + sd$ lines then it scores 0. If it falls between $+1sd$ and $+2sd$ or $-1sd$ and $-2sd$ then it scores 2. Between $+2sd$ and $+3sd$ or $-2sd$ and $-3sd$ then it scores 4 and above $+3sd$ or below $-3sd$ it scores 8. These values are normally recorded as positive values when above av and negative values when below av . The values of each observation are summed until an observation occurs on the opposite side of the central line to the previous observation, when the sum is re-set to zero before adding the current value. A process is defined as out of control if the cumulative score is greater than 7 (or less than -7).

The zone control chart requires the same information as the other two: values for av and sd . In the examples that follow, I am using the recommendation from the AMC brief that sd is estimated using “Nelson's suggestion” (nothing to do with telescopes and blind eyes!). Nelson⁸ suggested that a good estimate

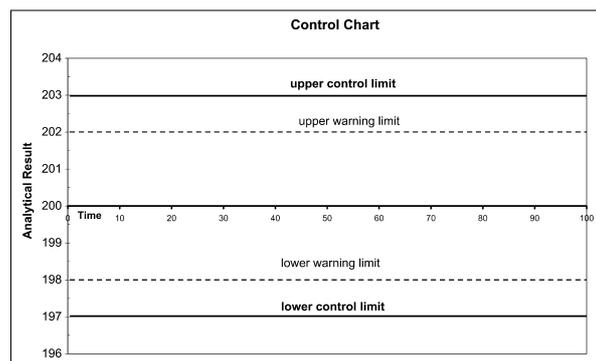


Figure 1. A process control or Shewart chart.

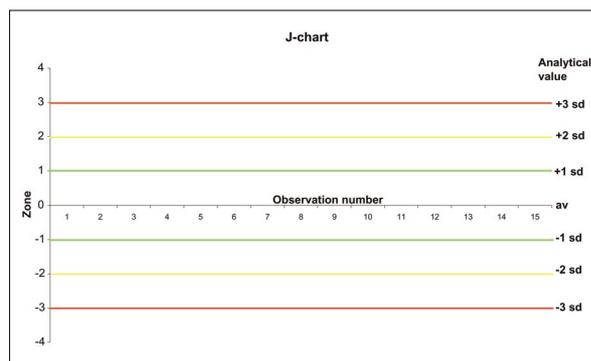


Figure 2. The set-up for a J-Chart.

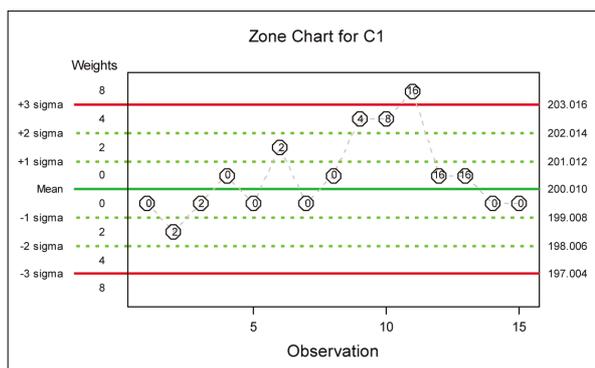


Figure 3. An example of the MINITAB® implementation of the J-chart.

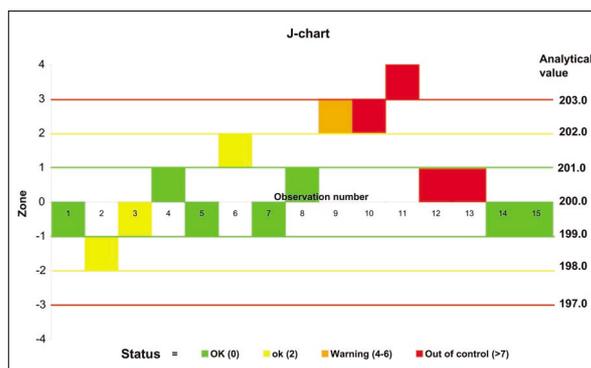


Figure 4. The colour coded version of Figure 3.

of an *sd* of a small set of values could be obtained by calculating an average moving range and multiplying it by 0.8865. The moving range is calculated by summing the absolute differences between successive pairs of numbers (i.e. ignoring the sign) and dividing by the total number of pairs. Obvious outliers should be excluded from these calculations.

Example

The first example of the J-chart is a plot as implemented in the statistical package MINITAB®. My calibration data consists of 20 observations which conveniently average 200 and have an *sd* of 1.0. The test data are 15 values which have been selected to demonstrate the operation of the chart. Looking at Figure 3 we can see the cumulative sum is plotted inside each circle indicating the position of each observation. The importance of reading these values will be appreciated when the rule for “out of control” is recalled: greater than 7 or less than -7. While it is obvious that the process is out of con-

trol at the eleventh observation (because it is above the $+3sd$ line), according to the rule it is out of control at the tenth observation and remains out of control until the 14th observation when the sum was reset to zero.

The coloured J-chart

As readers of this column will know, I am very enthusiastic about the advantages of plotting in colour. So I wondered if colour would be a useful addition to the J-chart and I believe that I have found a real advantage, not just a pretty picture. What I found disappointing about the J-chart was the requirement to read and interpret the value of the cumulative sum. My small modification is to plot a colour coded value of the cumulative sum so that it is very easy to see when the process is out of control, see Figure 4. This chart was produced by a somewhat laborious Excel® spreadsheet (available without any warranty).

I am grateful to Tom Fearn for producing the example from MINITAB®

and for helpful discussions and advice. The possibility of a MATLAB® program is being considered and if it has sufficient interest it may become the subject of the next in our series about matrix algebra.

References

1. F. Page, *The Observer*, 16 December (1973).
2. A.M.C. Davies, *Eur. Spectrosc. News* No. 79, 18 (1988).
3. A.M.C. Davies, *Spectrosc. World* **2(5)**, 36 (1990).
4. R.J. Howarth, www.rsc.org/lap/rsccom/amc/amc_index.htm.
5. A.F. Bissell, *An Introduction to CuSum Charts*. Institute of Statisticians, Bury St Edmunds, UK (1984).
6. A.H. Jaehn, *TAPPI J.* **87**, 159 (1987).
7. A.H. Jaehn, *Qual. Prog.* **24**, 65 (1991).
8. L.S. Nelson, *J. Qual. Technol.* **14**, 172 (1982).