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Special Issues in Semiconductor Manufacturing

EECS 290H
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PROBLEM SET No. 6
Due on Thursday 8th of April 1999, at the beginning of the class

1. Two decision rules are given below. Assume they apply to a normally distributed quality characteristic. Further assume that the control chart has 3-sigma control limits.

   Rule 1: If one or more of the next seven samples yield values of the test statistic that fall outside the control limits, conclude that the process is out of control.

   Rule 2: If all of the next seven points fall on the same side of the center line, conclude that the process is out of control.

   What is the overall a-risk for each of these rules?

   *We can analyze **Rule 1** with the help of the binomial distribution. In this context, we are to perform seven trials and each one of the has a probability α to generate an alarm. The probability that no alarms will be generated is then $(1-\alpha)^7$. The probability that one or more alarms will be generated is $1 - (1-\alpha)^7 = 1 - (1-0.0027)^7 = 0.0187$.*

   *We can analyze **Rule 2** with the help of the binomial distribution as well. The probability that all seven points will be on the same side of the centerline is 0.5^6 (since we do not care on which side of the centerline the first point is, as long as the remaining six points are on the same side. The probability that an alarm will be generated is then $0.5^6 = 0.0156$.*

2. In the semiconductor industry, the production of microcircuits involves many steps. The wafer fabrication process typically builds these microcircuits on silicon wafers, and there are many microcircuits per wafer. Each production lot consists of between 16 and 48 wafers. Some processing steps treat each wafer separately, so that the batch size for that step is one wafer. It is usually necessary to estimate several components of variation: within-wafer, between wafer, between lot; and the total variation.
   a. Suppose that one wafer is randomly selected from each lot and that a single measurement on a critical dimension of interest is taken. Which components of variation could be estimated with these data? What type of control charts would you recommend?

This estimates the TOTAL amount of variation (i.e. the sum of lot-to-lot, wafer-to-wafer and across-wafer). A simple x-bar chart would be sufficient.

   b. Suppose that each wafer is tested at five locations (say, the center and four points at the circumference). The average and range of these within-wafer measurements are xww and Rww, respectively. What components of variability are estimated using control charts based on these data?

xww captures the wafer-to-wafer variability, in addition to the lot-to-lot variability. Rww captures the across wafer variability. Both variables should be tracked with a simple x-bar chart for each. The reason Rww should be tracked with an x-bar chart is because it represents mostly deterministic variability, and statistically it behaves as the difference between averages, so it needs a chart based on the normal distribution, such as the x-bar chart.

   c. Suppose that one measurement point on each wafer is selected and that this measurement is recorded for five consecutive wafers. The average and range of these between-wafer measurements are xBW and RBW, respectively. What components of variability are estimated using control charts based on these data? Would it be necessary to run separate x and R charts for all five locations on the wafer?

xbw captures the lot-to-lot variability. Rbw captures the wafer-to-wafer variability. Running separate charts for each location on the wafer would be statistically correct, but logistically difficult, and also difficul6t to interpret on the production floor.

d. Consider the question in part (c). How would your answer change if the test sites on each wafer were randomly selected and varied from wafer to wafer?

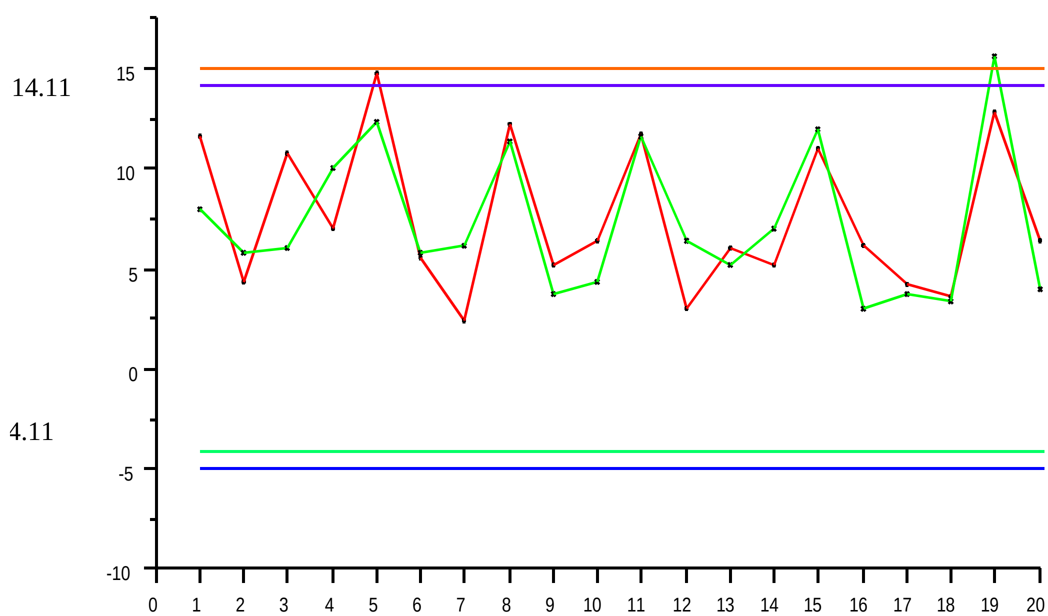
In this case, Rbw would also capture the across-wafer variability.

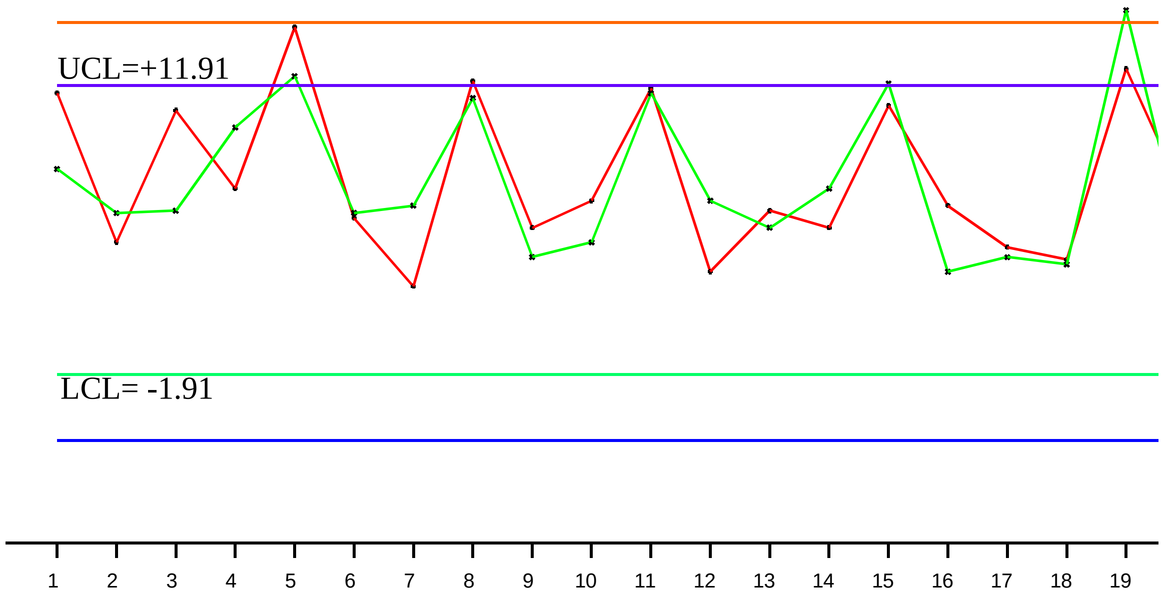
e. What type of control charts and rational subgroup scheme would you recommend to control the batch-to-batch variability?

I would take the average of several pre-determined points across a wafer, and would select several wafers from the batch, in a pre-determined fashion. The grant average of these measurements would fluctuate mostly because of batch to batch variability.

3. Assume that the specs of the above problem are 1.95 - 2.15 µm.
a) Construct a modified control chart with 3-sigma limits, assuming that if the actual process fraction nonconforming is as large as 5%, the process is unacceptable.
b) If the actual process fraction nonconforming is as large as 5%, we would like the modified control chart to detect this out-of-control condition with probability 0.9. Construct the modified chart, and compare it to the chart obtained in part (a).

Plotting just the deviations from 2.00, I calculate LCL and UCL and plot the two wafer means separately. From my numbers I see that the sigmas of the first and the second wafer are essentially the same.





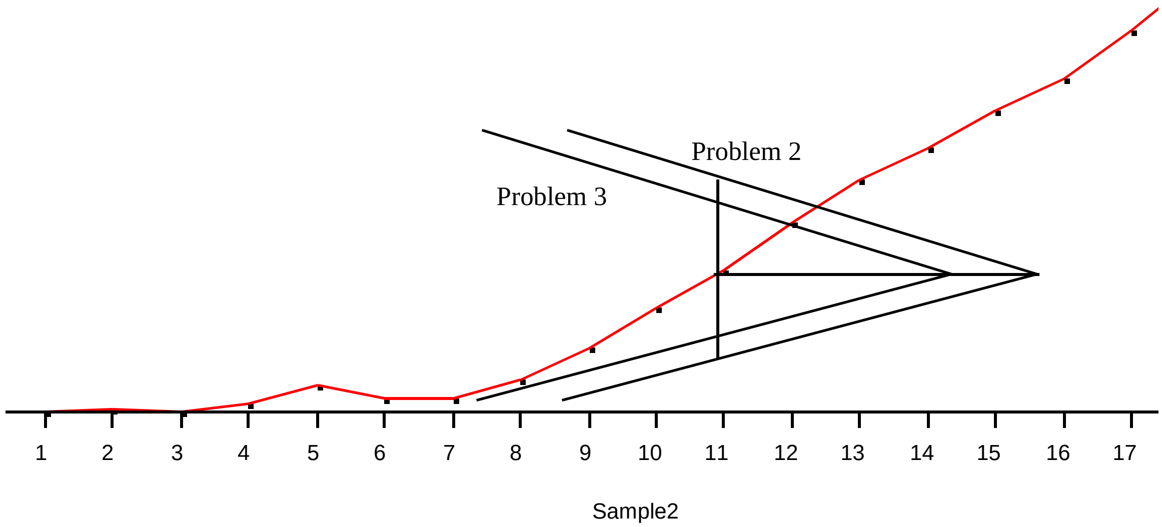
4. Consider the data below (σ=2.0, n=5):

Sample Number	$\bar{x}$	Sample Number	$\bar{x}$
1	10.45	11	11.39
2	10.55	12	11.69
3	10.37	13	11.51
4	10.64	14	11.28
5	10.95	15	11.38
6	10.08	16	11.25
7	10.50	17	11.63
8	10.87	18	11.88
9	11.25	19	11.46
10	11.46	20	11.67

Suppose it is necessary to design the cumulative-sum control chart to detect a shift in the process mean of 1.3 units and that L(0) = 500. Design this cumulative-sum control chart

From table 7.2, I use δ=1.3/(2.0/2.24)=1.45. I could choose to interpolate, however, to simplify things, I simply choose the closest table entry. The closest table entry is at δ=1.5, L(0)=500, and that gives me an

$L(\Delta)$=5.4 and a d=4.7, and $(A/\sigma_{\bar{x}})\tan\theta = 0.75$. If I choose $A = 2\,\sigma_{\bar{x}}$, then θ=20.55^o



5. Suppose that in the previous problem the analyst wishes to find a cumulative-sum control chart that has $L(\Delta)<=4.0$. Does the chart designed in the last problem have this property? If not, design a new chart. What is L(0) for this cumulative-sum control chart?

No, it does not. I can accomplish this if I set d=3.3, θ=20.55^o, for which $L(\Delta)$=4.0.

6. Design a cusum procedure with α=0.005, β=0.20, D=1, σ=3, and n=5. Set up both the V mask and the parameters K and H for the tabular scheme. Assume that the target value μo=50.

$\Delta = 1$ and $\sigma = 3 \Rightarrow \sigma_{\bar{x}}=1.34$ and $\delta = 0.745$

$d = (2 / \delta^2) * \ln((1 - \beta) / \alpha) = 18.3$

$\theta = \arctan(\Delta / 2 * A) = \arctan(1 / (2 * 2 * \sigma_{\bar{x}})) = 10.56^o$

$k=\Delta/2 = 0.5$ and $H = 2 * d * \sigma_{\bar{x}} * \tan(\theta) = 9.14$