2.830J / 6.780J / ESD.63J Control of Manufacturing Processes (SMA 6303)
Spring 2008

Massachusetts Institute of Technology

Department of Mechanical Engineering
Department of Electrical Engineering and Computer Science

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Assignment 3
Out 2/26/2008; due Tuesday 3/4/2008

Part 1 — qq plots and testing the assumption of normality

A silicon wafer is patterned with an array of dies of identical *design*. When the wafer is cleaved to separate the dies, each die will become a single integrated circuit. Each die contains many MOSFETs that are wished to have identical dimensions. In reality, these dimensions vary within each die *and* the mean within-die dimension varies from die to die. A particular dimensional parameter of the MOSFETs produced in die 1 (near the edge of the wafer) is described by $x_1 \sim N(0,1)$ and the same parameter of the MOSFETs in die 2 (near the wafer's center) is described by $x_2 \sim N(d,1)$. A metrology expert presumes that die-to-die variability will be negligible in comparison with within-die variability, and therefore samples 500 transistors from die 1 and 500 transistors from die 2, intermingling the samples before analyzing them. In other words, the expert discards any information about which measurement comes from which die. For values of d from 0 to 2 in steps of 0.5, use your favorite graphing software to simulate these intermingled samples. Also generate a sixth sample for the case $d = 4$. Produce a qq-norm plot of each generated sample. If you had been given these qq-norm plots, without knowing their source, and had been asked to say which of the samples were taken from a normal distribution, what would you have said?

Subjective interpretation of qq-norm plots has its limitations. There are, however, quantitative tests of normality that can be used. The Lilliefors test, for example, tests the hypothesis that the distribution underlying a given sample is normal. In MATLAB's Statistics Toolbox, this test is implemented as `lillietest(X, alpha)` where `X` is a vector containing the samples and `alpha` is the level of significance at which the hypothesis is to be tested. The MATLAB function returns 0 if the hypothesis of normality is accepted, and 1 if rejected. What is the smallest value of d for which the hypothesis of normality of the intermingled sample is rejected by the Lilliefors test at the 5% level? Comment on what you find. (If you prefer to use a different test of normality, please feel free to do so.)

Note: an additional resource on engineering statistics for semiconductor (and other manufacturing processes) is the *NIST/SEMATECH Engineering Statistics Handbook* at http://www.itl.nist.gov/div898/handbook/index.htm . This handbook includes descriptions of normality tests, as well as many other tools and methods we use throughout this class.

Part 2 — hypothesis testing

Montgomery: problems 3–3, 3–6, 3–11, and 3–21

Part 3 — control charts

May and Spanos: problems 6.1, 6.2, and 6.3

Part 4 — process capability

Montgomery: problems 7–3 (data are in spreadsheet "3-4.xls"), and 7–6
May and Spanos: problem 6.8

Part 5 — thermoforming production process

The data from a thermoforming production process that was run at NTU is presented in the spreadsheet `3-5.xls'. During this short production run all inputs were held as constant as possible (or so it was thought).

From prior production runs, we have concluded that

$$\overline{\overline{x}} = 34.75$$
$$\overline{S} = 0.17$$

(a) Create control charts for this process for the sample sizes of 3 and 5.

(b) Using the Western Electric rules, does the process ever indicate an out-of-control condition? If so, at what sample number?

(c) Assume the design specs for this product are such that historically the process capability has been $C_p = C_{pk} = 1$. How many out-of-specification parts would be produced if at each new measurement you immediately applied the Western Electric rules? (Be sure to compare the run chart with the xbar charts to answer this question.)

(d) If we wanted to detect a mean shift of 0.25σ, what would be the ARL for this process?

(e) If no SPC had been performed on this process during this entire production run, how many defective parts would have been produced?