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

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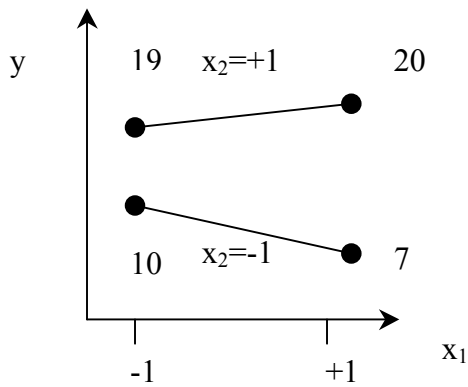
Massachusetts Institute of Technology  
 Department of Mechanical Engineering  
 2.830J/6.780J Control of Manufacturing Processes

Quiz 2  
 April 26, 2007  
 Open Book and Notes

NOTE: Read each problem carefully; very little calculation is necessary to solve them.  
Please sketch the requested plots carefully and as to scale as possible.

Problem #1 (50%)

A two factor two-level full factorial experiment has been performed without replication. The results are summarized in the following plot and table:



Experiment #	$x_1$	$x_2$	$y$	$\hat{y}$	$\varepsilon$
1	-1	-1	10		
2	+1	-1	7		
3	-1	+1	19		
4	+1	+1	20		

ANOVA Table (To be filled in)

source	sum of squares	d.o.f.	mean square	F ratio
average	$SS_{ave} =$			
factor $x_1$	$SS_{x_1}$			
factor $x_2$	$SS_{x_2}$			
residual	$SS_R$			
total	$SS_T$			

a) As the problem progresses, you will fill in the following ANOVA table. You need not fill it in first, but be sure it is complete when you finish this problem.

b) For this data, fit a response surface using the model:

$$\hat{y} = \beta_0 + \beta_1 x_1 + \beta_2 x_2$$

and use it to fill in the  $\hat{y}$  column in Table 1

c) Using this model, calculate the residuals and enter these in Table 1

d) To 95% confidence is  $\beta_1$  significant? To 95% confidence is  $\beta_2$  significant? Give specific confidence levels to which  $\beta_1$  and  $\beta_2$  would be considered significant.

Now we run four additional center point experiments (NB: do not use these in creating the ANOVA table of part a)

Experiment #	$x_1$	$x_2$	$y$
5	0	0	14
6	0	0	15
7	0	0	14
8	0	0	13

e) What is your estimate of the experimental error now?

f) Now re-evaluate your conclusions from part c). To 95% confidence is  $\beta_1$  significant? To 95% confidence is  $\beta_2$  significant? Give specific confidence levels to which  $\beta_1$  and  $\beta_2$  would be considered significant.

Problem #2 (30%)

A test on a welding process has been performed to determine if arc length has an effect on the width of the resulting weld. The experience of operators is that it does not affect the average width, but it does affect the variability of the welds.

The data is as follows:

Voltage	Weld Width					Mean	Std Dev
	1	2	3	4	5		
10	0.09	0.10	0.13	0.08	0.07	0.094	0.0230
12	0.06	0.09	0.12	0.07	0.12	0.092	0.0277
14	0.11	0.08	0.08	0.05	0.06	0.076	0.0230
16	0.19	0.13	0.15	0.20	0.11	0.156	0.0385

- a) Does the voltage have any effect on the width of the weld? (Please specify how confident you are in your answer.) (Please note that you are given the sample standard deviation for each level, which should simplify any calculations you need to make)
- b) Design a test to determine if there is any truth to the notion that voltage increases the variability of the weld width. (Just set up the test, but do not implement it.)
- c) Sketch (Carefully!) Shewhart and CUSUM charts for this data assuming that arc voltage has not been changed (i.e. assume all of the data is for identical input conditions). Be sure to sequence the data row by row. (If helpful you can scale all the data by 100 for this plot.)
- d) Does this analysis change your conclusions from parts a) and b).

Problem #3 (20%)

A series of residual plots from a two level experiment are shown on the following page. For each of these plots (a-j) describe (in words) what is happening in each case. Where appropriate comment on how the model could be changed to reduce the residual.

NB: Note carefully the x axis on each plot, as they are not all the same.

