QC LAB
A MICROCOMPUTER LABORATORY IN QUALITY CONTROL

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ABSTRACT

A laboratory exercise is described that provides a student with an opportunity to apply the concepts of mean and sigma or range charts to a simulated production process. The student is asked to develop a decision strategy, select a sample size and make a series of decisions for the production process which is simulated on a microcomputer. At the end of the exercise the results secured are compared with those of a strategy programmed into the computer which uses the same information available to the student. Results secured using this program in a quality control class are discussed.

INTRODUCTION

All too often applied statistics courses are taught as pure theory courses where the student only needs to learn the appropriate formulas and solve problems by plugging numbers into the formulas. It is often difficult to determine whether one has in fact secured an appreciation for the application of statistics to real problems or whether one has merely learned some methods that may not prove to be useful when faced with real data. This paper describes one of a number ‘of computer programs that ask the student to make decisions when faced with randomly generated data in a situation where the best decision is not necessarily obvious. The results secured from the decision making of the student are then compared with the results secured by a computer strategy that uses the same information available to the student.

Quality Control is one of the applied statistic areas that is currently of particular interest as the entire area of manufacturing becomes of increasing concern. The statistics of quality control can generally be broken down into the two areas of 1) estimating process parameters and thus the ability of a process to meet specifications, and 2) maintaining control of the process through sampling to detect any problems that may arise. This experiential exercise is aimed at the second of these areas, assuming that a good process has been established and that the problem faced is one of maintaining the process at the desired level.

The object of the exercise is to minimize the sum of three costs. These three costs are inspection cost, cost of bad parts produced, and cost of resetting the process to the original parameters. Inspection cost is assumed to be a constant cost per unit inspected, cost of bad parts is assumed to be a constant value for each unit that does not meet specifications, and cost of resetting the process is assumed to be a constant value per reset regardless of whether the process needed resetting. These costs are assigned arbitrary values for initial play but may be reset by the user for future plays. The run size from which a sample is to be drawn also has an arbitrary value that can be changed for future plays.

The student chooses whether to use the sample range or the sample sigma as a measure of dispersion and then selects the sample size (the number to be inspected)
for each production run. The same sample size must be used throughout the simulation which is designed to continue for 100 production runs. After each production run the sample data are given and the student is asked to either continue to the next production run without making any changes or to reset the system and then continue to the next production run.

After 100 production runs the results secured by both the student and the computer strategy are given, followed by a tabulation of the changes that occurred during the simulation as well as the system resets made by both the student and the computer.

INSTRUCTIONS

The specific instructions given each student are as follows:

<u>QCLAB</u>

QCLAB is a game that simulates a quality control problem. You are asked to sample the product being produced and decide whether or not the process producing the product has changed to the extent that you should spend the money needed to correct the change and return the process to its original level.

At its original level the production process will be producing a normal distribution with mean equal to 100 and standard deviation equal to 5. Resetting the system at any point will return the process to these values.

Specifications on the process are set at 85 and 115. Units produced that are less than 85 or greater than fl5 are considered to be defective, while units between 85 and 115 are considered to be good. Operating at its original level, 0.27 of 1 percent of the product produced will be defective.

A production run will consist of 250 units. (This may be changed for different plays of the game but the first time through the standard value of 250 should be used.) At random intervals a change in either the mean or the standard deviation of the process may occur. The process will then operate with these new values until it is either reset or another random change occurs.

The object of the simulation is to minimize total cost by detecting changes and resetting the system when they occur. The three costs involved are:

1. The cost of inspecting each unit is $1.00
2. The cost for each defective unit produced is $3.00
3. The cost of resetting the system is $100.00

(These costs may be changed for different plays of the game. The first time through the standard values should be used.)

You will be asked to select a sample size. This will be the number of units inspected from each production run and, once selected, will be the same throughout the game. You will then be given the sample mean and either the sample range of the sample standard devia tion. The sample range will be the difference between the largest and smallest value In the sample, while the sample standard deviation will be calculated as the square root of the sum of the squared deviations about the sample mean divided by the sample size.

You will be competing against a computer strategy that experiences the same random changes you are experiencing. At the conclusion of the game you will be shown both your costs and the computer's and also given a tabulation of what changes occurred and when resets took place. The simulation is designed to be run for 100 production runs and then automatically gives you final results. During play you will be asked to enter 0, 1, or 9 after each production run. Entering 0 causes the process to continue and generates a new sample. Entering 1 resets the system and generates a new sample. Entering 9 ends the program and gives the same results as normally given after 100 production runs. This should only be used if it is necessary to end the program before the full 100 production runs can be completed.

Sample Run

An abbreviated sample run follows:

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              FRAZER SIMULATION LABORATORY
                     QUALITY CONTROL

STANDARD VALUES ARE
    INSPECTION COST            $1 PER PART
    DEFECTIVE PARTS COST       $3 PER PART
    RESETTING SYSTEM COST    $100 PER RESET

    RUN SIZE IS 250 PARTS

DO YOU WANT TO USE STANDARD VALUES?(Y/N)Y

WOULD YOU LIKE TO USE RANGE OR SIGMA FOR SAMPLE
DISPERSION?
ENTER 1 FOR RANGE, 0 FOR SIGMA
 0
SIGMA WILL BE THE ROOT MEAN SQUARE OF THE DEVIATIONS
FROM THE MEAN

WHAT SAMPLE SIZE WOULD YOU LIKE TO USE?
 9

WE ARE NOW READY TO BEGIN THE GAME
AFTER EACH SAMPLE YOU WILL HAVE THREE CHOICES
ENTERING 0 GOES ON TO NEXT SAMPLE VALUES
ENTERING 1 RESETS THE SYSTEM
ENTERING 9 ENDS GAME AND GIVES FINAL RESULTS
GAME WILL END AUTOMATICALLY AFTER 100 SAMPLES

SAMPLE          MEAN          SIGMA
 1             117.6595       5.190511
ENTER 0,1, OR 9
 1
SAMPLE          MEAN          SIGMA
 2             99.32674       3.970349
ENTER 0,1, OR 9
 0
SAMPLE          MEAN          SIGMA
 3             99.03146       4.273945


 12            98.69445       5.040365
ENTER 0,1, OR 9
 0
 13            99.67006       3.735258
ENTER 0,1, OR 9
 0
 14            104.1104       3.59144
ENTER 0,1, OR 9
 1
 15            99.54158       2.838422


ENTER 0,1, OR 9
 0
 25            99.63222       2.540492
ENTER 0,1, OR 9
 0
 26            99.34765       1.695583
ENTER 0,1, OR 9
 0
 27            107.0331       5.199722
ENTER 0,1, OR 9
 1
 28            96.32558       4.627217


 32            102.8655       5.13138
ENTER 0,1, OR 9
 0
 33            107.222        3.347836
ENTER 0,1, OR 9
 1
 34            101.309        4.083001


ENTER 0,1, OR 9
 0
 36            96.89215       3.020762
ENTER 0,1, OR 9
 0
 37            101. 9222      6.468977
ENTER 0,1, OR 9
 0
 38            99.82178       7.920627
ENTER 0,1, OR 9
 1
 39            98.56841       4.367516


 74            101.8555       4.174888
ENTER 0,1, OR 9
 0
 75            90.36956       5.053715
ENTER 0,1, OR 9
 1
 76            93.18404       5.129381
ENTER 0,1, OR 9
 1
 77            98.93643       3.286603
ENTER 0,1, OR 9
 0
 78            100.1512       3.378182


 99            98.10654       3.300687
ENTER 0,1, OR 9
 0
 100           101.349        4.848687
ENTER 1 TO GO ON
 1
TOTALS FOR SIMULATION
    TOTAL PARTS PRODUCED = 25000
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                              YOU          COMPUTER
% OF PARTS OUTSIDE SPECS      1.169435     1.251965
COST OF SAMPLING              900          500
COST OF BAD PARTS             877.0762     938.9738
COST OF RESETTING             700          400
TOTAL COST                    2477.076     1838.974

UNIT COST IN CENTS            9.908304     7.355895

NOTE ABOVE AND ENTER 1 FOR SUMMARY OF CHANGES
 1
VALUES SHOWN ARE GENERATED CHANGES AND YOUR SYSTEM
RESETS

SAMPLE      MEAN          SIGMA      TYPE CHANGE
 1            117.9147      5        MEAN CHANGE
 1            100           5        SYSTEM RESET
 14           100           5        SYSTEM RESET
 27           100           5        SYSTEM RESET
 33           104.6433      5        MEAN CHANGE
 33           100           5        SYSTEM RESET
 38           100           5        SYSTEM RESET
 75           91.30322      5        MEAN CHANGE
 75           100           5        SYSTEM RESET
 76           96.92762      5        MEAN CHANGE
 76           100           5        SYSTEM RESET
 88           99.99274      5        MEAN CHANGE
COMPUTER RESET AT  1  38  75  76
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From the sample run we see that the person running the exercise elected standard values, to use sigma as the measure of dispersion, and to use a sample size of 9. In sample 1, the mean of 117.6595 appeared unduly large, and the system was reset. In sample 14, the mean of 104.1104 also appeared to be unduly large, and the system was again reset. The sample 27 mean of 107.0331 similarly provoked a reset, as did the sample 33 mean of 107.222. The sigmas of samples 37 and 38, 6.468977 and 7.920627, were both quite high and the system was again reset. A mean of 90.36956 and another of 93.18404 on samples 75 and 76 resulted in two more system resets.

Following sample 100 end results are given showing that the computer strategy had a considerably lower sampling (inspection) cost, a slightly higher bad parts cost, and a considerably smaller resetting cost, giving a total cost less than 75 percent of the person running the program. This indicates that for this program a somewhat smaller sample size and less willingness to reset the system without strong evidence of a change would have given better results. The program then goes on to tabulate the changes that occurred. This shows that the reset made after sample 1 was necessary, while those made after samples ~ and 27 were not. The reset made after sample 33 was also a good one while that made after sample 38 was not. The resets made after samples 75 and 75 were both necessary. The mean change to 99.99271k on sample 88 was not detected and did not have enough effect on the ability of the process to produce good parts to justify resetting even if it had been detected.

The program also shows that the computer reset after samples 1, 38, 75, and 76. The major changes on samples 1, 75, and 76 were all picked up immediately while the somewhat smaller change on sample 33 was not detected immediately, resulting in the somewhat higher cost of bad parts for the computer strategy.

RESULTS SECURED

The results secured from using this program, especially in terms of student acceptance, have been most gratifying. Many students run the simulation over and over, and virtually all of them say they got a much better feel for statistical quality control from using it. Some of the comments offered by students follow:

“The simulation exercise made quality control come alive for me!”

“My biggest mistake was to reset the system too often. The main thing I learned was not to rely so much on my intuition and to place more trust in the control charts.”

“Communicating with the computer was fascinating. Knowing that a new decision had to be made each time that new data arrived was an exciting challenge.”

“The experience drives home the point that good statistical quality control means cost minimization.”

“The exercise provided practical experience in setting up and using quality control charts. It also gave me a good idea of what will be expected in an actual ‘on the job’ problem.”

The basic concepts of this quality control program have been developed for some time and have been previously reported on. However, several improvements have been made recently, the most important of which is the addition of the computer strategy which had not been part of the original program. Without the computer strategy to compare results with, the cost figures were not particularly meaningful and analysis of results secured stemmed mostly from the tabulation of the changes that occurred. The program was only used after students had already had considerable exposure to the statistics of quality control. With the addition of the computer strategy we now use the program in the first week of the quality control class before the concepts of small samples and three sigma control limits have been covered. Students whose background has been in traditional statistics tend to use very large sample sizes and tend to be very quick to reset the system, usually resulting in very high costs, often very much higher than those shown in the sample program. This experience certainly makes them very receptive to the theory of quality control as it is presented.

We then have them reuse the program after control chart theory has been presented and ask them to try to concentrate on doing a better job of detecting changes than merely using the standard three sigma decision rule employed by the computer strategy. Some students get very good at using more sophisticated decision rules and learning something of what works well, particularly when the cost parameters and run sizes are changed. Nearly all agree, however, that it is quite difficult to do much better than the traditional three sigma decision rule and believe that its simplicity makes it an odds on choice for on the job use.

SUMMARY

Everything in our experience indicates that this computer simulation, providing a hands-on laboratory for the statistical quality control course, is a most worthwhile addition to the course. Student acceptance is very good, and they are exposed to actually working with concepts that they would otherwise only have textbook knowledge of. There are almost no drawbacks to using such programs, and we strongly recommend this and similar programs for student use.

REFERENCES

1. Grant and Leavenworth, Statistical Quality Control, McGraw-Hill, 1980.

2. Bommer and Frazer, "A Time-Sharing Computer Laboratory in Quality Control," Journal of Quality Technology, October 1976.