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AN INSTRUCTIONAL COMPUTER SIMULATION OF TAMPERING IN QC

Dongping Nie, University of Utah
Susan A. Chesteen, University of Utah

ABSTRACT

With increased availability of computers and more affordable plotting software in business schools, the task of teaching some of the important principles of quality control in an effective way is placed in a new perspective. This paper presents an innovative way of teaching the concepts of process variation and tampering using a computer simulation TAMPER. The simulation helps students visualize the effects of process tampering, a common problem in quality control. Aside from a brief account of the precursor experiment, we discuss program issues and simulation results as well as the benefits of TAMPER as an experiential learning tool in quality control.

INTRODUCTION

Some two thousand years ago the ancient Chinese philosopher, Laotsu, taught his pupils that: governing a big state is like cooking a small fish, you do not overdo it. Recently this same line of reasoning found its way into the business world under a new name, tampering (Deming, 1986; Gitlow, et.al., 1989). As one of the pioneers in the field of quality control W. Edwards Deming put it, "if anyone adjusts a stable process to try to compensate for a result that is undesirable or for a result that is extra good, the output that follows will be worse than if he had left the process alone" (Deming, 1986).

It is no secret to most practitioners in the business world that overcontrol of processes occurs often when management attempts to improve these processes based on the discovery of just one defective or just one customer complaint without profound knowledge of the consequences. Loss to an organization due to tampering can be unexpectedly costly.

Boardman et. al. (Gitlow et. al., 1989) proposed the following table-top experiment to help visualize the effects of tampering with a process. The physical requirements for the experiment include a funnel, a marble that will fall through the funnel, a flat surface, a pencil for marking the landing places of the marble, and a holder for the funnel (Figure 1). The marble is dropped repeatedly through the funnel and for each drop its position is marked. Five rules for adjusting the funnel between consecutive drops are used to demonstrate the effects of different adjustment patterns on the final outcome. However, as an experiential method for teaching the effects of tampering during one class period, this experiment has several shortcomings. The actual conduct of this experiment is virtually impossible due to its time-consuming nature and the difficulty in accurately recording and plotting all landing points. A more viable alternative to demonstrate this same concept of tampering with a process is to utilize computer simulation.

The use of computer simulations as teaching tools has proliferated in business schools (Frazer, 1984; Naylor, et.al., 1966; Sanders et.al., 1978; Sekely, 1984). In particular, the application of simulation techniques in quality control has proven to be both valuable and efficient in educational settings. For example, Frazer developed and successfully utilized a computer laboratory exercise involving student decision-making for a production process.

Following the lead of instructors such as Frazer, the authors created a computer simulation TAMPER for classroom use to assist in teaching several principles in Quality Management, a newly developed course designed for MBA and Ph.D. students. A broad range of topics were treated in the course including such subjects as quality management from a strategic point of view, general concepts of quality control, economic analysis of quality costs, and a technical attack on product quality to detailed methods of statistical quality control. The control of variation is a major task of quality control in production. In addition to the manual production of control charts and plots, we also asked our students to perform exercises using QSOM (a software of Quantitative Systems for Operation Management). To further extend the experiential learning aspect of the course, we created our own computer program TAMPER to simulate the effect of tampering with a production process. The primary objectives of the simulation TAMPER are to help students understand the concept of variation in QC, to investigate the effects of process tampering, and to appreciate the advantages of computer simulation as an experiential learning method.

DESCRIPTION OF TAMPER

TAMPER is a computer program that simulates the act and consequences of tampering with a process, a common quality control problem. It consists of two FORTRAN programs: (1) "RWALK.FOR" which generates data points representing the landing places of the marble in the previously described physical experiment and (2) "PLOT.FOR" which graphically presents the results of RWALK.FOR in the form of scatter plots and control charts. FORTRAN was the chosen language because of its flexibility in coding, its versatility in graphics, its rich library, and its wide acceptance by students (Naylor, et.al., 1966; Pidd, 1984; Pritsker, 1986).

"RWALK.FOR" uses an IMSL (International Mathematical and Statistical Library) subroutine RNSPH. RNSPH generates a random number vector, each component of which locates an arbitrary point on a unit circle. Users of our program may incorporate any other reliable random number generator to replace RNSPH if so desired. It takes less than 5 seconds to generate 100 data points on a VAX 11/750.

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"PLOT.FOR" is more system dependent than "RWALK.FOR" due to the existence of a variety of plotting software and hardware. HANDYPAK was employed in our example because of its availability.

DESCRIPTION OF RULES

The pattern of data points generated by "RWALK.FOR" is governed by the rules used in the design of the program. The first four rules closely follow Boardman's original design. The *fifth* rule is actually a variation of rule 3. Conceivably, interested readers can invent additional rules and attempt to discover their perspective impact on the final outcomes. The five rules we used are:

Rule 1: Set the funnel over the target at (0,0) and leave the funnel fixed through all 100 drops. The final outcome using this rule is displayed in Figure 2 which shows the pattern of points forming a ring. The fact that all 100 points are not located at (0,0) is evidence of the presence of a limited amount of variation without any tampering.

Rule 2: The funnel, is set over the target at (0,0) prior to the initial drop; let (X_k, Y_k) represent the point where the marble dropped through the funnel comes to rest on the surface. Rule 2 states that the funnel should be moved a distance (-X_k, -Y_k) from its last resting point. From Figure 3, we can see that the ring generated by Rule 1 was made dimmer' and less defined. This demonstrates that there is more variation present due to the tampering effect.

Rule 3: The funnel is set over the target at (0,0) prior to the initial drop; let (X_k, Y_k) represent the point where kth marble dropped through the funnel comes to rest on the surface. Rule 3 states that funnel should be moved a distance (-X_k, -Y_k) from the target (0,0). A bow tie shaped scatter plot is generated by this rule (Figure 4). The appearance of this pattern provides even more evidence of the phenomenon of variation.

Rule 4: The funnel is set over the target at (0,0) prior to the initial drop; let (X_k, Y_k) represent the point where kth marble dropped through the funnel comes to rest on the surface. Rule 4 states that the funnel should be moved to the resting point on the surface (X_k, Y_k). A rather irregular shape (Figure 5) appears as a result of this rule.

Rule 5: The funnel is set over the target at (0,0) prior to the initial drop; let (X_k, Y_k) represent the point where kth marble dropped through the funnel comes to rest on the surface. Rule 5 states that the funnel should be moved distance (-X_k/2, -Y_k/2) from the target (0,0). This is a modification of Rule 3 where the distance of the moves has been reduced by one half. In sharp contrast with the results from Rule 3, the data points are much more confined (Figure 6). This pattern indicates that less variation results if the magnitude of the tampering is reduced in each step.

EVALUATION OF OUTCOMES USING CONTROL CHARTS

The scatter plots only provide a general idea of the resultant variations. To further understand the impact of tampering, these criteria are provided by the PLOT.FOR in the form of control charts. Control charts for individual, units are special statistical charts for process control where sample size equals one. This occurs frequently when automated inspection and measurement technology are used and every unit manufactured is analyzed (Montgomery, 1985). Since the subgroup consists of single measurement, there is no variation within the subgroups themselves. Therefore, the estimate of the process variation has to be derived from the variation between the successive observations. The control chart has two parts: one for the process mean and one for the process variability.

The formula for \bar{X} chart is:
centerline: \bar{X}
Upper control limit: $\bar{X} + 3 R/d_2$
Lower control limit: $\bar{X} - 3 R/d_2$
where $d_2=1.128$, (since the moving range n is 2)

The formula for R chart is following:
centerline (moving range): R
Upper control limit (moving range): $D_4 \cdot R$
Lower control limit (moving range): $D_3 \cdot R = 0$
where $D_3=0$ and $D_4=3.267$ when $n=2$.

DISCUSSION OF RESULTS

The two variables, X and Y are symmetric. The process for constructing and analyzing the control charts for the variable X is the same as for Y. So we have chosen to construct control charts for X as an illustration of the use of control charts in the analysis of the resultant variations.

Figures 7-11 display and R control charts for X derived by TAMPER subject to the various rules. The reader may observe from an analysis of these figures that they reveal, unequal amounts of process variation. Each control chart is distinctive and allows the reader to detect whether the process is in control. The following discussion assists in the discrimination process and the interpretation of the results.

Basically, the process for Rule 1 is within the R control limits and X control limits (Figure 7). However, there are three points slightly above the upper R control limit. Management's use of the first rule demonstrates an understanding of the distinction between special and common variation, and the different types of managerial action required for each type of variation (Gitlow, et.al., 1989).

It is clear that control charts for rule 2 (Figure 8) show more variation than those for rule 1.

The R control chart for rule 3 (Figure 9) shows a significantly different pattern from the other

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R-charts. Even though the X chart is still within the limits, the process is out of control. The R control chart signals that managers and operators with inadequate knowledge who "attempt" to reduce the variation by somehow "compensating for what is lacking in the previous step will ultimately create more variation through this effort.

The R chart for rule 4 is entirely within the control limits (Figure 10) because of the way the points are generated (each point is not farther away from its previous point by one step size). Though the X chart shows no points off the limits, as a practical rule, a run of more than seven consecutive points having the same signs indicates the process is out of control. Also, the scatter plot along with the X chart reveals that the mean deviation from the origin point grows as the square root of the number of data points (Spitzer, 1976). Deming called this phenomenon "a man who matches color from the match to batch for acceptance of material, without reference to the original swatch" (Deming, 1986). Setting the current inspection policy based on the previous record is an example of rule 4.

Recall that Rule 5 is an alteration of Rule 3 where there is a lesser degree of tampering and therefore less variation is produced. Control charts (Figure 11) produced using these two different rules are excellent examples for visualizing how the effects of variations are related to the degree of the tampering.

SUMMARY

TAMPER is a computer simulation, which provides students with a hands-on laboratory experience for the control of variation. Through the visualization of the effects of overcontrol, students gain a better understanding of the concept and causes of variation.

For classroom purposes, The computer simulation of the experiment was found to be both efficient and effective. We first introduced TAMPER to the students in a classroom presentation focussed on the use of simulation as a quality control tool. Students were interested in the idea of the funnel experiment as well as the computer simulation. Their immediate reaction was to ask which programming language was used and whether they could run the computer simulation by themselves. At this suggestion, we refined and improved the program to make it more user friendly. Because classroom time was a limiting factor, we only showed the students the whole procedure of operating this program. They were fascinated by the moment when random points began appearing on the color monitor screen. The feedback we received has prompted us to install it for future use for both teaching and research.

TAMPER is expeditious, flexible, and inexpensive. It

accomplishes the same goals as the actual physical experiment and its results are more accurate. Students commented that it was a vivid and direct way to learn the concept of tampering.

The results of this simulation illustrate the effect of overadjustment of a process. The use of this Simulation should help a person realize that attempting to correct or improve a process without profound knowledge of the process will only exacerbate the problems. Improvement of the process cannot be achieved through tampering.

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FIGURE 1
FUNNEL EXPERIMENT

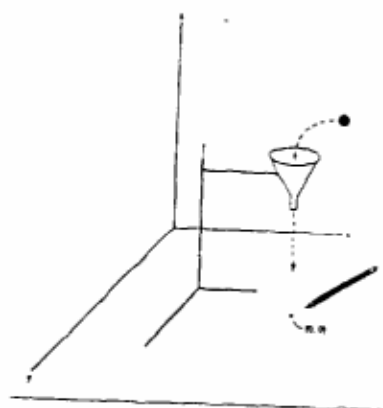


FIGURE 2
SCATTER PLOT(RULE 1)

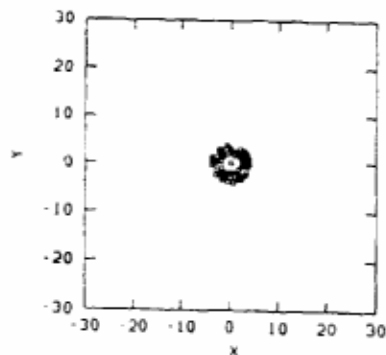


FIGURE 3
SCATTER PLOT(RULE 2)

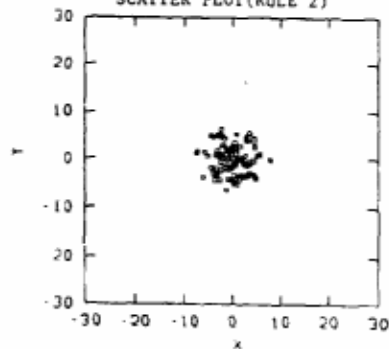


FIGURE 4
SCATTER PLOT(RULE 3)

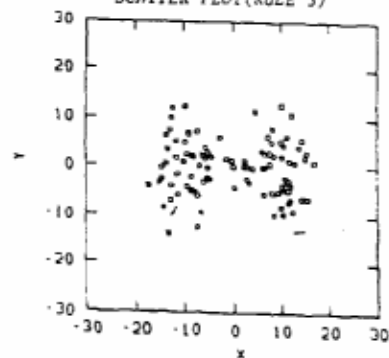


FIGURE 5
SCATTER PLOT(RULE 4)

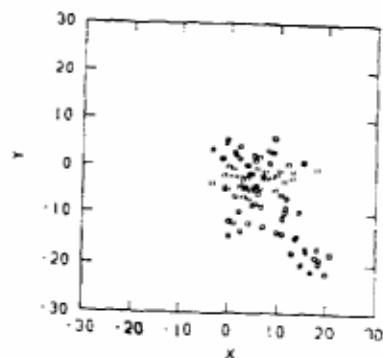


FIGURE 6
SCATTER PLOT(RULE 5)

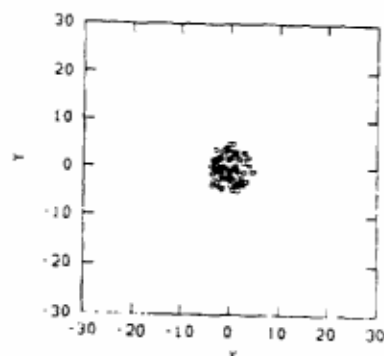
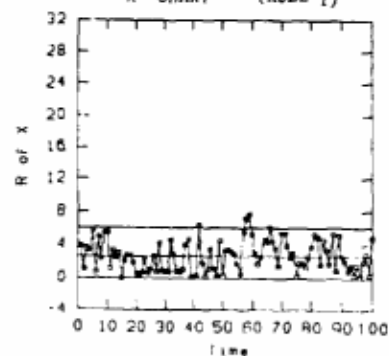


FIGURE 7
R CHART (RULE 1)



X-bar CHART(RULE 1)

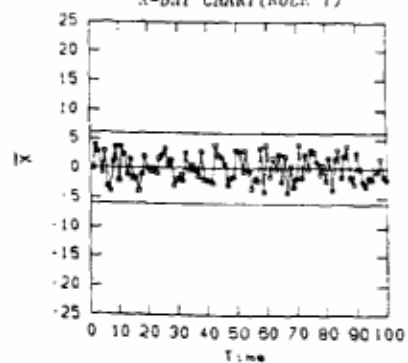
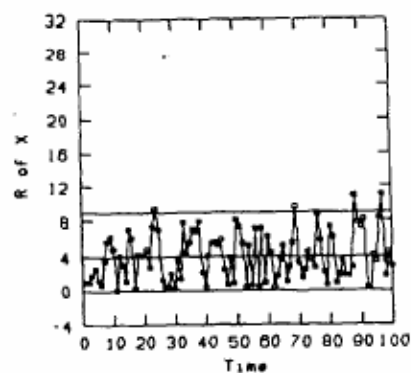


FIGURE 8
R CHART (RULE 2)



X-bar CHART (RULE 2)

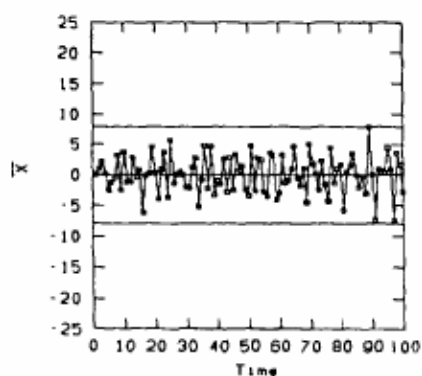
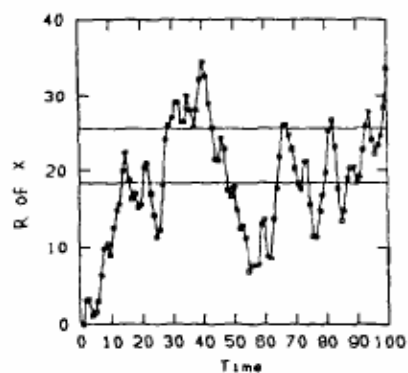


FIGURE 9
R CHART (RULE 3)



X-bar CHART (RULE 3)

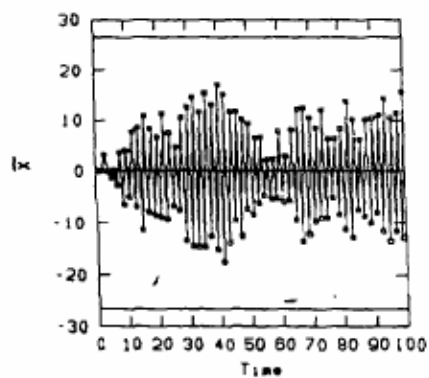
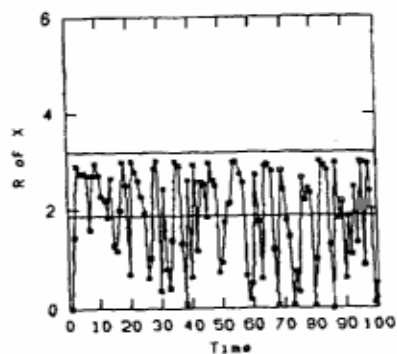


FIGURE 10
R CHART (RULE 4)



X-bar CHART (RULE 4)

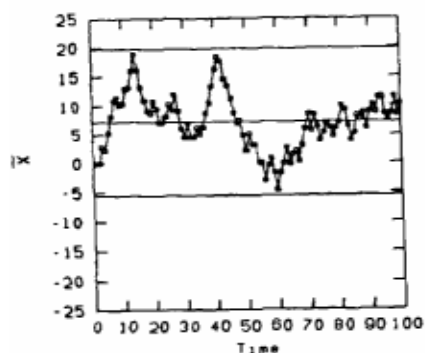
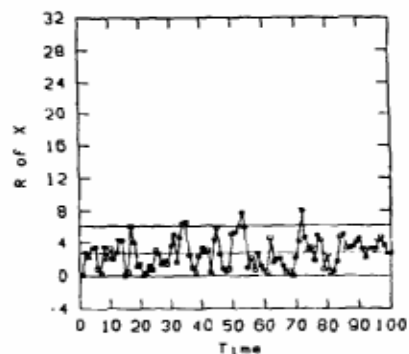


FIGURE 11
R CHART (RULE 5)



X-bar CHART (RULE 5)

