SPC Provides Strategic Guidance for Automation Investments

How to capitalize on the partnership between SPC and automation

by Hans J. Bajaria

AUTOMATION HAS THE POTENTIAL TO BOTH improve the productivity of manufacturing processes and increase the quality of their output. Functional automation mainly offers greater speed, while process control automation is applied mainly to improve the consistency of process output. An investment in the latter can best pay off in a timely manner when guided by statistical process control (SPC).

A simple scenario illustrates the desirable partnership of automated process control and SPC: the use of SPC to monitor any process output will indicate instabilities (out-of-control conditions) in the order that they occur. As the causes for such conditions are discovered, corrective actions must be taken to restore the process to its natural (in-control) state. If such conditions occur frequently, standard operating procedures (SOPs) must be developed to eliminate or prevent them. Once these procedures are proven to be consistently effective, they can be automated so that their execution will not depend on human judgment or motivation. The process then becomes self-correcting and remains stable without intervention.

Process control issues can be broken down into two basic categories:

1. Process control for already known process disturbances
2. Process control for unknown process disturbances

Actions taken to correct known disturbances are considered deterministic controls. Corrective actions against unknown disturbances are called probabilistic controls.

Process control for known disturbances

Figure 1 identifies three elements of process control that can play a role in perturbing the condition of process output, namely: human hands, standard operating procedures, and process parameters. Deterministic controls are necessary to monitor and correct the known relationship between each of these process control elements and the process output.

Suppose that SPC is used to track the output of a manual process. With consistent use of SPC by operating personnel, it would be possible to keep the process in a state of statistical control. However, if automation is used instead of human hands, not only can the process be maintained in a state of statistical control with greater certainty, but its capability will be much improved over that which can be achieved by human hands.

Standard operating procedures are developed to improve output consistency. Suppose the SOP calls for a tool change after every 300 parts are processed. Execution of this procedure cannot be guaranteed, since it is dependent on the knowledge and motivation of the operating personnel. Since SPC reveals the causes of instabilities, it will certainly reveal violations of SOPs. (Using SPC to discover SOP violations, however, is certainly not an effective use of SPC.)

Automating SOPs, on the other hand, will ensure that they are followed, preventing violations from occurring. Decisions to automate SOPs, along with the most economic execution of SOPs, should be based on SPC knowledge.

There are many process parameters (e.g., temperature, pressure, feed, speed, cure time, loading rate, etc.) that can affect the consistency of process output. These parameters must be controlled within well-defined ranges to obtain acceptable process output consistency. Problems in keeping process variables within prescribed ranges occur for basically two reasons: equipment limitations and eager but unskilled problem solvers who over-control the process. Over-control of incapable processes would produce a larger proportion of defectives than what would otherwise be the case.

Here again, the partnership between SPC and automation is well illustrated. SPC can reveal the cause of violations of prescribed process parameter ranges, while automation can provide real-time signals to alert operating personnel to violations and needed process corrections. Going one step further, automation can provide closed-loop feedback to automatically correct violations.

Process control for unknown disturbances

Even well-planned manufacturing operations are prone to problems, the causes of which are often hard to predict in advance. SPC is the only tool that can provide true signals for all process disturbances, even when their origin is unknown. The proper execution of SPC requires that process output signals be monitored authentically and on a real-time basis, using appropriate statistical control charts, and that actions be taken based on the interpretation of these charts.

Many companies use control charts on a selective basis only, rather than as a rule. Their main concern is for product specifications, rather than statistical control limits. Corrective actions are taken only when the parts are out of specification range. Proper use of SPC, however, requires that actions be taken when parts are out of statistical control limits. In both approaches, the part conditions are examined; the difference between approaches focuses on when and why corrective action is initiated.

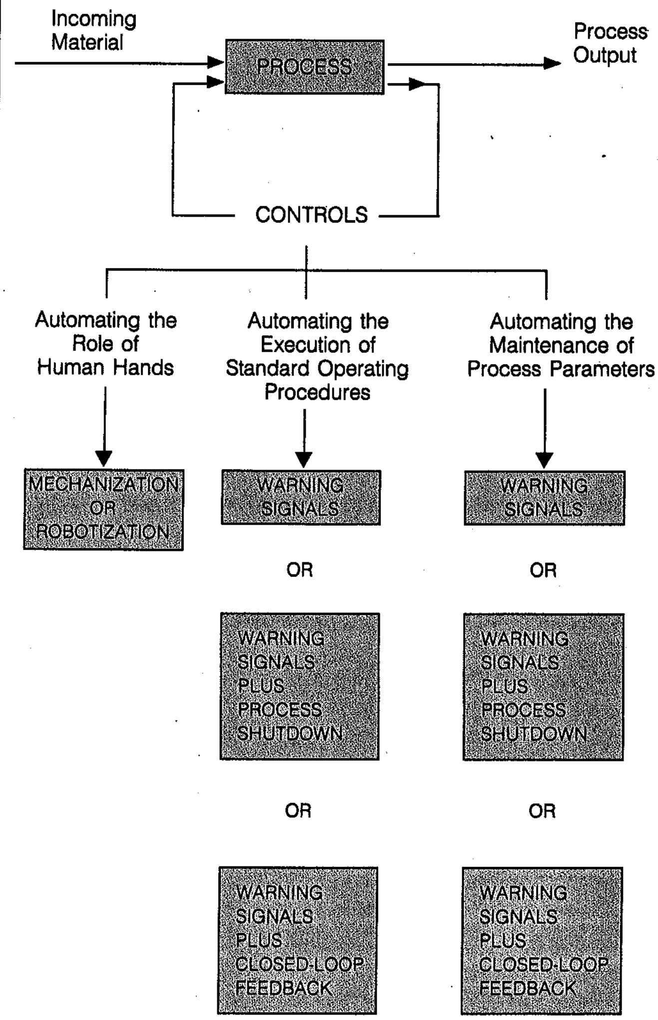
A major problem in properly implementing SPC is that the work force is habituated to think in terms of specification limits and not control limits. (Process adjustments based on specification limits either cause under-control for capable processes or over-control for incapable processes.) The control chart concept can be illustrated with simple mathematics in the classroom. However, it is very hard to execute the idea on the production floor due to conventional thinking habits. To further complicate the situation, decisions made using control limits sometimes coincide with those possibly made using specification limits, creating an argument in favor of the status quo.

To successfully implement SPC, it must be emphasized that when decisions to take action on a process are based on control limits, the actions will always be correct. On the other hand, decisions based on specification limits will sometimes be correct and sometimes incorrect. To use control limits in determining corrective actions against unknown causes, several steps must be executed:

1. Measure the process output (i.e., product characteristics of interest).
2. Record the output as raw data.
3. Plot an authentic summary of these data on the appropriate control charts on a real-time basis.
4. Interpret the control charts as each point is added to the charts.
5. Determine the corrective action.
6. Take the corrective action.

These six steps form the basis for probabilistic controls. The first requirement in the use of these controls is an understanding of the relationships between the process output and the disturbing causes through the use of control charts. To that end, process output signals are statistically monitored, with their interpretation depending on the use of statistical tools. As process knowledge is gained through the use of SPC, automation can be phased in economically and effectively. Figure 2 highlights the stages of automation that are possible in implementing probabilistic controls.

Figure 1.
Various Elements of Deterministic Process Controls That Can Be Automated in Different Stages



Stage A. Process output is measured manually. A measurement device can be plugged into the data storing device, which can then be used to generate appropriate control charts. The operator still has to handle the measuring device.

Stage B. Process output is automatically measured, with the desired statistical information held in a data storing device. The data storing device itself can generate an appropriate control chart, or it can be plugged into a computer to do the same. Several manual steps that might be required in measuring, summarizing, and plotting are eliminated. At this stage, interpretation of the control chart pattern is still based on the skill of the chart reader.

Notable disadvantages of this automation stage are a possible prohibitive gage cost and possible difficulty in buying off-the-shelf measurement technology to measure all of the process output characteristics of interest.

Stage C. Control chart interpretation is automated. The question of interpretation has always bothered SPC enthusiasts. In fact, insurmountable difficulties in reading the charts and determining corresponding hardware actions have resulted in apathy toward implementing SPC. For reliable interpretation, process changes must be noted as soon as they occur, and the condition of some top suspect variables must be tracked along with each plotted point. Many failures in reading charts are associated with the incompleteness of such records.

Tracking potential suspects along with plotted signals on the control charts can be automated. The algorithm to automatically signal the condition when the varying pattern on the control charts begins to coincide with the varying pattern of the suspects can be programmed into the computer. The algorithm should be able to examine not only the patterns followed by the individual suspects, but also those that are followed by all possible combinations of suspects. Automating control chart interpretation can reduce the tedious task of relating output patterns to suspect patterns to determine the corresponding hardware actions.

Stage D. Simulation methods are added. Even after Stage C efforts, the control charts might still be hard to interpret. The next level of sophistication gives the analyst the ability to ask some what-if questions with the aid of computer simulation methods.

The Monte Carlo simulation procedure is quite powerful. The analyst first chooses (guesses) the type and degree of perturbation in the suspected process variables and then describes this perturbation in the form of a mathematical model. A Monte Carlo program (a tool that has what-if questioning ability) is next used to generate control charts that reflect this scenario, and the simulated control charts are compared to the actual control charts. If the simulation generated based on one or more guesses in fact duplicates the actual (observed) control chart pattern, the analyst is then able to explain these observations.

Stage E. Corrective actions are automated. After having interpreted the control charts, SPC has provided all that it can deliver. Next, hardware actions to correct the process must be taken. Such corrections can be of two types: "turnable knobs" (referring to readily or economically adjustable process variables), which alter process parameters such as temperature, pressure, cure time, speed, feed, and loading rate; and "unturnable knobs" (referring to uncontrollable or expensive-to-control process variables), which alter process parameters such as material variation, worn tools, and operator fatigue. Automation can maneuver turnable knobs to restore the process to its natural state or can flash a message indicating the most probable unturnable knobs that are responsible for the patterns observed on the control charts.

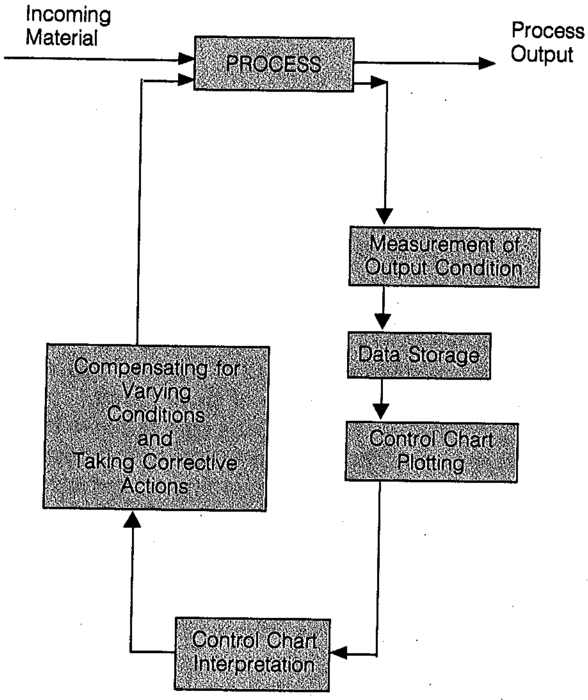
Stage F. Compensating actions are automated. The ultimate automation will use the forgiving nature of some process variables to compensate for changes as they occur. For example, if harder material than usual needs to be processed, this condition can be detected by the integral process control charts. Correspondingly, the speed of the machine can be reduced to achieve acceptable process output signals. The presence of forgiving process variables makes a process flexible.

Both process knowledge and process flexibility must exist at this highest level of automation. Process flexibility is not unusual, and for many manufactured products, process knowledge either already exists or can be developed and refined with the aid of statistical methods.

Predicting the unknown is never easy, but statistical thinking (SPC) combined with high-speed computers (automation) at least makes the task manageable for most processes, and can solve many problems that cannot be approached by any other equally effective means.

In his newest book, *The Frontiers of Management*, Peter F. Drucker reinforces the importance of adding automation to enhance quality improvement efforts: "Automation builds quality standards and quality control into every step of the process. Equally important, it spots and advertises a deficiency in quality the moment it occurs and at the place where it occurs. And it does so at no extra cost."

Figure 2.
Various Elements of Probabilistic Controls That Can Be Automated in Different Stages



Strategic automation decisions

Automation investments should be balanced among functional automation, automated deterministic process controls, and automated probabilistic process controls. There is sufficient evidence, however, to suggest that more dollars are spent on functional automation (speed) than on process control automation. Further, funds for process control automation are disproportionately distributed in favor of deterministic process controls.

There is an acute need to understand the relationships between the patterns in the process output and the corresponding contributing causes. This can be done only through the use of probabilistic methods. If the process of applying probabilistic controls is speeded up through the use of automation, greater benefits will be derived than by simply installing automated deterministic controls without first knowing strategic priorities.

Whenever it is unclear how funds should be distributed among the various forms of automation, SPC should serve as a conclusive guide toward setting priorities. SPC and automation form a profitable partnership when SPC provides the strategic guidance as to what needs to be done, and automation ensures that it gets done.

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