Line # | Program Statement | Comment
--- | --- | ---
10 | EDIT MONITOR [ENDLINE] | Creates a file named "MONITOR"
20 | DELAY 0.0 | Speeds up program execution.
20 | DSP "Production MONITOR" @ WAIT 2 | Displays program title.
40 | REAL N | Delegates "N" a precision numeric variable.
50 | WS = " @ W[20] = " | Clears the HP71 Display.
60 | IMAGE 256,# | Formats display for "Window" and "number of Failures".
70 | DSP USING 0,W[2],N | Displays latest "Window" and number of failures.
80 | | BEGINNING of data entry routine.
90 | TOCP | Select routine based on operator input: GOOD, BAD, or QUIT.
100 | KS = KEYE@ @ pos* + Q",K[1],S+1 | Input GOOD, BAD, or QUIT.
110 | GOTO 100,"good", "bad", "quit" | A production process begins with the flow of the various parts and materials that are used to build a product; the process ends when the packaged product is shipped to the customer. Between these points are all the procedures, techniques, testing, and work that make up the process of converting those parts and materials into your product. When the process is operating properly and product statistics are as expected, the product will be of consistent (expected) quality. If something goes wrong – if the product builds, reworks, or fails too many times – customers will find out, and your product may lose its market share.
120 | GOODF | Input "cause of failure" code.
130 | IF NOT POS( ",", W[2],.J) THEN N = N + 1 | Add a BAD unit failure code letter to lower case.
150 | | Displays latest "Window" and number of Failures.
160 | BAD | Statistical Process Control
170 | IF NOT POS(",", W[2],.J) THEN N = N + 1 | Statistical process control is the use of numbers and data to analyze production processes. Statistical procedures are used to set the statistical limits for your process, that is, to determine how much your process can vary from the expected norm and still be in control.
180 | DSP "Cause of Failure ", CHS(90); | The HP71's role in statistical process control is to compare your process data with these calculated or historical statistical limits. This comparison is then used by the HP71 to monitor your process to assure that it is delivering the desired level of product quality.
190 | KS = KEYE@ @ IF NOT POS("DC",K[3]) THEN 190 | Statistical methods are used to distinguish normal variation from emerging problems in your system. The "continuous updating" and "moving window" techniques explained below are powerful statistical tools for keeping your product at a high level of quality. These techniques involve gathering data obtained from tests or measurements on each unit of product taken at selected points in the manufacturing cycle, and periodically updating the appropriate statistics on that data. The HP71 is ideally suited for calculating and storing such information.
200 | GOTO 190, "GOOD", "BAD", "QUIT" | Using the HP71 for Production Process Monitoring
210 | | The first step in establishing a production process monitoring system is to determine the normal deviations in the process and which deviations indicate that the process is (going) out of control. The techniques described in AT&T's Statistical Quality Control Handbook tell you how to make these determinations.
220 | | Next, you determine where in your process deviations are most likely to occur, for example, in assembly, test, incoming and outgoing inspection, and repair stations. You then place the HP71 in these locations to monitor the process.
230 | | Using the HP71 for Production Process Monitoring
240 | | Using an HP71 system to monitor your production process allows you to:
| | • Set the number and causes of defects (including purchased parts)
| | • Monitor product parameters such as size and weight (when connected to appropriate digital instrumentation)
| | • Determine the time needed to perform an operation
| | • Monitor repairs and rework for additional information about Hewlett-Packard's handheld computers in manufacturing solutions, call the HP office nearest you and ask for your local sales representative. Local HP sales offices are listed in the white pages of your local telephone book.
| | Hewlett-Packard
| | Handheld Computer and Calculator Operation
| | 100 N.E. Circle Blvd.
| | Corvallis, Oregon 97330

For Reference: Statistical Quality Control Handbook
Western Electric Company
Indianapolis, IN 46226
The HP71 can be programmed to allow an operator to record production data for a process station with one or two keystrokes. The HP71 can then compare that data with the statistical limits for the process to ensure that the process is under control. If too many failures, or too many failures of one type, occur, or if too much time is taken for a particular operation, the HP71 can indicate that the process is out of control. Patterns in the production data that the HP71 gathers can then be analyzed to determine the cause of the deviation in the process, so you can take corrective action.

When a new unit is entered in the HP71, the computer's real-time clock can log the time of data entry and the elapsed time since the previous unit was entered. Thus, the HP71 can automatically track the time taken for completing a procedure. If the procedure time changes from the statistically expected time, such changes can be a change in the normal process, and the process may be considered to be out of control. Evaluation of the cause for the time change (for example, production tool wear or a delay in material delivery) helps you to correct the cause and restore the process to your statistically expected norm.

The HP71 can also monitor the number and types of repairs that are being done. Too many repairs or too many repairs of one type may indicate a critical assembly or test procedure. You can then correct the procedure, so that only good units are produced.

Continuous Updating Example

The first example illustrates a continuous updating statistical technique for production process monitoring.

The XYZ Company sells breakfast cereal. The FDA requires that the food weight be printed on each box in which the cereal is packaged and specifies two limits:

- The amount by which the food weight can be less than the amount printed on the box
- The maximum number of boxes per 100 that can be less than the printed weight

The XYZ Company must satisfy these limits set by the FDA and, to avoid losing money, to avoid losing money, stay within the upper weight limit it sets for itself.

To accomplish this, the production line is set up to randomly divert 10 boxes out of every 100 to a manual digital scale connected to an HP71 through an HP11 or an HP13B interface.

The HP71 updates the production data after each box of cereal is weighed; if too many boxes exceed the required limits, the HP71 signals that the production line requires adjustment to restore process quality.

The process data are then archived daily for presentation to the FDA. (The day's production data can be downloaded from an HP71 to the XYZ Company's data bank via an HP11 link.)

Moving Window Example

The second example illustrates the moving window concept of statistical quality control in production process monitoring.

In this example, the HP71 is being used primarily for monitoring the production process -- not for calculating statistics. (The process limits have already been calculated statistically and should be rechecked periodically by the production engineers to verify that they are still valid. Consult the reference for more information.)

For illustration purposes, here is a simplified example with only three possible failure modes:

- The new unit doesn't turn on
- The unit draws excessive battery current
- The unit doesn't pass its internal diagnostic test

The program listed below stores test results in the computer from the last 20 units produced. As each new unit is tested, the test data are entered into the HP71, replacing the data on the oldest (20th) unit. Thus, the statistics are always on the last 20 units produced, which comprise the moving window.

The historical data we have suggest that, when our process is in control, we will see two failures or less per 20 units (a 10% maximum reject rate). Thus, if the process is going out of control, the HP71 may catch it quickly.

The program for this example (written in HP71 Enhanced BASIC) establishes a "window" that is 20 units in length and presents the contents of the window in the HP71 display, along with the number of defective units from the last 20 entered. In this example, the manufacturing process is in control if more than two defective units appear in the window (i.e., a 10% maximum reject rate). Units move from right to left in the display as they are entered into the HP71. As the test results for the latest unit appear on the right, the results for the 20th unit "fall off" the left end of the display -- hence the name "moving window."

A good unit is represented by a "O", and defective units are identified by failure code letters: "P" for power-on failure, "C" for excessive battery current drain, and "D" if the new unit fails the internal diagnostic test. The numeral on the right end of the display is the number of defective units in the last 20. These "recedes" are visible in the displayed "window."

To try out this example on the HP71, set the computer in the PROGRAM mode (cursor should be at the left end of the display) and type in the program listed below. To start the program, enter "RUN MONITOR" into the HP71, and then press [ENTER]. The following table lists all four possible test results and the required HP71 keystrokes responses.

<table>
<thead>
<tr>
<th>IF</th>
<th>PRESS HP71 KEY</th>
<th>DISPLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit passed all tests - GOOD</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Unit failed any of tests - BAD</td>
<td></td>
<td>Add a DOT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cause of Failure:</td>
</tr>
<tr>
<td>If the (C) key is pressed, the HP71 prompts you for the failure mode. Press one of the following keys:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit failed Power-on test</td>
<td></td>
<td>Add p to window</td>
</tr>
<tr>
<td>Unit failed Excess Current test</td>
<td></td>
<td>Add e to window</td>
</tr>
<tr>
<td>Unit failed Diagnostic test</td>
<td></td>
<td>Add d to window</td>
</tr>
</tbody>
</table>

The following figure is an example of an out-of-control-process display window showing 5 GOOD units (p), a "Power-on" failure (p), an "Excess Current" failure (e) and a "Diagnostic" failure (d). The numeral 3 on the right is the number of failures appearing in the 20-unit window:

```
| p | p | p | e | d | d | d |
```

Pressing the (C) key ends the program.

This simple example of statistical process control can be expanded to accommodate your production needs. For instance, the numerical quantities of failure modes can be stored in arrays, [p], [e], [d], and so on, for later retrieval and analysis; the number of failures "N" per lot WNR [r] can be changed to suit the process; and the number of failures of one type can be calculated to assist you in determining what corrective action is needed to improve your production process. If digital sensors are used for input to the HP71, the program will need slight modification to allow the program to assign the ASCII key code values (for selected keys) to the input variable K5.

Summary

The following program illustrates the potential of the HP71. This handheld computer can deal with complex situations and perform sophisticated statistical analyses. Its computing power can help to solve your most difficult production problems. The HP71 can perform as a stand-alone computer at individual work stations. It can also be used as a module in an HP 8240A HP-II Interface Module, to communicate with other devices such as printers and digital voltmeters.

An excellent source of information for using the HP71 with digital instruments is a booklet entitled "HP71 Instrument Control Systems." This publication contains information about converters from HP11 to other interfaces such as HP1B, RS-232C, or RS-170 video. It also gives brief descriptions of several HP71 instruments and peripherals for the HP71.

Sophisticated HP71 networks (HP71 product application note 3204-1312) can be configured with a master loop connecting several HP71 nodes to a host computer. Each node consists of an HP71 with two HP11 loops -- one loop for control of local measuring devices and the other loop for communication with a host computer. Each node can use its own program(s) to interact with the instruments, so that an operator can determine the state of a process at that point. Communications with the host computer may include status reports on individual work stations and alarm messages to tell the operator that a process is going out of control.
Continuous Updating Example

The first example illustrates a continuous updating statistical technique for production process monitoring.

The XYZ Company sells breakfast cereal foods. The FDA requires that the food weight be printed on each box in which the cereal is packaged and specifies two limits:
- The amount by which the food weight can be less than the weight printed on the box
- The maximum number of boxes per 100 that can be less than the printed weight

The XYZ Company must satisfy the limits set by the FDA and, to avoid losing money, stay within the weight limit set for itself.

To accomplish this, the production line is set up to randomly divide 10 boxes out of every 100 to an automatic digital scale connected to an HP-71 through an HP-110 or an HP-3B interface. The HP-71 updates the production data after each box of cereal is weighed; if too many boxes exceed the required limits, the HP-71 signals to the production line to adjust to restore process quality.

The process data are then archived daily for presentation to the FDA. (The day's product data can be downloaded from an HP-71 to the XYZ Company's data bank via an HP-110 link.)

Moving Window Example

The second example illustrates the moving window concept of statistical quality control in production process monitoring.

In this example the HP-71 is being used primarily for monitoring the production process — not for calculating statistics. The process limits have already been calculated statistically and should be rechecked periodically by the production engineers to verify that they are still valid. Consult the reference for more information.

For illustration purposes, here is a simplified example with only three possible failure modes:
- The new unit doesn't turn on
- The unit drains excessive battery current
- The unit doesn't pass its internal diagnostic test

The program listed below stores test results in the computer from the last 20 units produced. As every new unit is tested, the test data are entered into the HP-71, replacing the data on the oldest (20th) unit. Thus, the statistics are always on the last 20 units produced, which comprise the moving window.

The historical data we have suggest that, when our process is in control, we will see two failures or less per 20 units (a 10% maximum reject rate). Thus, if the process is going out of control, the HP-71 can catch it quickly.

The program for this example (written in HP-71 Enhanced BASIC) establishes a "window" that is 20 units in length and presents the contents of the window in the HP-71 display, along with the number of defective units from the last 20 entered. In this example, the manufacturing process is in control if more than two defective units appear in the window (i.e., a 10% maximum reject rate).

Units move from right to left in the display as they are entered into the HP-71. As the test results for the latest unit appear on the right, the results for the 20th unit will be removed from the left. Thus, the data are referred to as "moving windows." A good unit is represented by a "1," and defective units are identified by failure code letters: "F" for power-on failure, "E" for excessive battery current drain, and "D" if the new unit fails the internal diagnostic test. The number on the right end of the display is the number of defective units in the last 20. These "rejects" are visible in the displayed "window."

To try out this example on the HP-71, set the computer in the PROGRAM mode (cursor should be at the left end of the display) and type in the program below. To start the program, enter "RUN MONITOR" into the HP-71, and then press [ENTER]. The following table lists all four possible test results and the required HP-71 keystrokes responses.

<table>
<thead>
<tr>
<th>IF</th>
<th>PRESS HP-71 KEY</th>
<th>DISPLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit passed all tests — GOOD</td>
<td>[C]</td>
<td>Adds a DOT</td>
</tr>
<tr>
<td>Unit failed any of tests — BAD</td>
<td>[d]</td>
<td>Cause of Failure:</td>
</tr>
</tbody>
</table>

The if the (C) key is pressed, the HP-71 prompts you for the failure mode. Press one of the following keys:

- Unit failed Power-on test
- Unit failed Excess Current test
- Unit failed Diagnostic test

The following figure is an example of an output-of-control process display window showing 17 GOOD units (.), a "Power-on" failure (p), an "Excess Current" failure (e) and a "Diagnostic" failure (d). The numeral 3 on the right is the number of failures appearing in the 20-unit window.

pressing the [C] key ends the program.

This simple example of statistical process control can be expanded to accommodate your production needs. For instance, the number of quantities of failure modes can be stored in arrays, [p], [e], [d], and so on, for later retrieval and analysis; the number of failures "N" per lot W8I [can be changed to suit the process; and the number of failures of one type can be calculated to assist you in determining what corrective action is needed to improve your production process. If digital sensors are used for input to the HP-71, the program will need slight modification to allow the program to assign the ASCII key code values for selected keys to the input variable K5.

Summary

The following program illustrates the potential of the HP-71. This handheld computer can deal with complex situations and perform sophisticated statistical analyses. Its computing power can help to solve your most difficult production problems. The HP-71 can perform as a stand-alone computer at individual work stations, or it can be linked to one of HP's many other systems such as an HP 8204A HP-II Interface Module, can communicate with other devices such as printers and digital voltmeters.

An excellent source of information for using the HP-71 with digital instruments is a booklet entitled "HP-71 Instrument Control Systems" (5954-1241). This publication contains information about converters from HP to other interfaces such as HP-IB, RS-232C, or RS-232-C video. It also gives brief descriptions of several HP-71L instruments and peripherals for the HP-71.

Satisfactory HP-7L networks (HP-71 product application note 5954-1312) can be configured with a master loop connecting several HP-71L nodes to a host computer. Each node consists of an HP-71 with two HP-110 loops — one loop for control of local measuring devices and the other loop for communication with a host computer. Each node can use its own program(s) to interact with the instruments, so that an operator can determine the state of a process at that point. Communications with the host computer may include status reports on individual work stations and alarm messages to tell the operator that a process is going out of control.
### Using the HP/71 for Production Process Monitoring

#### Introduction

This application note provides information on how the HP/71 Handheld Computer can be used for monitoring your production processes. An example of a "continuous updating" technique for production process monitoring is included, and "moving window" process monitoring is illustrated by an annotated program which keeps track of good and defective units as they are entered into the HP/71 by your production workers (or by digital sensors connected to the HP/71 through an HPIL or an HPMB interface).

A production process begins with the flow of the various parts and materials that are used to build a product; the process ends when the packaged product is shipped to the customer. Between these points are all of the procedures, techniques, testing, and work that make up the process of converting those parts and materials into your product. When the process is operating properly and product statistics are as expected, the product will be of consistent (expected) quality. If something goes wrong—such as a product build time or rework increases, or if too many completed units (or sub-assemblies) fail their qualification tests—your process is said to be "out of control."

#### Statistical Process Control

Statistical process control is the use of numbers and data to analyze production processes. Statistical procedures are used to set the statistical limits for your process, that is, to determine how much your process can vary from the expected norm and still be in control. The HP/71’s role in statistical process control is to compute your process data with those calculated or historical statistical limits. This comparison is then used by the HP/71 to monitor your process to assure that it is delivering the desired level of product quality. Statistical methods are used to distinguish normal variation from emerging problems in your process. The "continuous updating" and "moving window" techniques described below are powerful statistical tools for keeping your product at a high level of quality. These techniques involve gathering data obtained from tests or measurements on each unit of your product, taken at selected points in the manufacturing cycle, and periodically updating the appropriate statistics on that data. The HP/71 is ideally suited for calculating and storing such information.

#### Production Process Monitoring

The objective of production process monitoring is to gather data (from the products on your production lines) that can be used to help you determine whether your process is in or out of control. If your process is out of control, this information will also help you to determine what corrective action is needed to adjust your process, so that it will produce the expected level of product quality. An additional benefit of gathering product data is a better understanding of your process, enabling you to exert tighter controls on your system, and increasing the efficiency and quality of your manufacturing operations.