

Improving the Computer-Human Interface: The Qualitative Monitor Display

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This article describes a new technique for displaying the information needed by DSN operators for monitoring station performance. Known as a "Qualitative Monitor," it presents continuous variables in quasi-analog form on a digital cathode ray tube (CRT) display. Color changes, field reverses and blinking symbols assist the operator in identifying variables that are within acceptable limits and in performing corrective action when needed.

I. Motivation

A significant part of a Deep Space Station (DSS) or Network Operations and Control Center (NOCC) operator's task is to determine if the station equipment is performing as it should, and to take corrective action if it is not. In many cases the assessment of performance requires the operator to study numbers on a CRT display and try to determine if they are within specified limits and if they are rising, falling or stationary. If he decides that a change is needed and starts to move a control, there is the additional question as to which way to move the control to get the desired effect. When the displayed number is a multidigit quantity, and perhaps displayed in "floating-point" format because this made the programmer's task easier, it is sometimes hard to decide just what the variable is doing, especially if the quantity is jittering around a threshold for change of scaling.

The Qualitative Monitor Display presents a key set of variables to the operator in a uniform format which permits him to tell at a glance the state of the information presented and whether any further study is need. Additionally, the display aids the operator in taking any necessary corrective action.

II. History

Although the DSN has made significant progress in the processing of data and in the available throughput of information, it has made significant but unsatisfactory choices in the manner in which information is presented to people operating or monitoring equipment and system performance. In this section, an analog is drawn by examining data presentation in aviation. It seems clear that DSN programmers took technically sound display approaches which did not yield a good computer-human interface.

Through the early history of aviation until about the middle 1950's, instruments were all analog devices: fuel gauges, oil temperature indicators, artificial horizon gyroscopes, etc. Safe operating limits were usually shown by colored striping on the meter face, usually green for "good," and yellow and red for "marginal" and "bad." The pilot could tell with a quick glance at the instruments if all the needles were "in the green" leaving him free to concentrate on maneuvering and navigation.

As the science of digital instrumentation developed, engineers were attracted by digital numeric displays that could

show numbers that represented the variables and could do this more "accurately," i.e., with more resolution. However, it developed that this was not the sort of information the pilot needed for control. When landing or taking off, he wanted to know if the engine was performing within required margins, not the exact temperature at a cylinder head or the precise oil temperature. For the actual control of the plane, a digital presentation of the heading added another complication: if your heading is now 303 degrees, and you want to turn to a heading of 129 degrees, should you turn right or left? In particular, the pilot must be able to immediately tell the attitude of the aircraft in instrument (within clouds) conditions. He could not afford the luxury of a complex interpretation of complex but accurate digital information. Hence the aircraft is instrumented with analog artificial horizons and a circular heading compass.

The numeric displays in aircraft are usually accompanied by bar-graph displays, colored regions on the face of an instrument or "good/bad" signal lights. Although CRT's are now in use on the more sophisticated aircraft, flight control information is presented as the old-fashioned artificial horizon, flight director, or digital gyroscope on the face of the screen. The analog display now is being built of electrons instead of cams, levers, gears, etc. The reason is quite simple: humans can interpret analog displays of complex information much more easily than digital displays.

III. Approach

The Qualitative Monitor Display is made up of a series of horizontal lines. A portion of each line represents the scale of an analog meter, with a rectangular marker moving back and forth like the pointer on an edge-view meter. The "meter" excursions are limited to 21-character positions, corresponding to scale values of -10 to +10 at the edges and 0 at the center. At the left of each line is a label which identifies the variable, for example, NOISE or S-DOPPLER. At the right of the scale, the numeric value is shown with limited scaling, and at the extreme right there is a three-character label that identifies a more detailed display where the operator can find further information on the variable presented in that line. An example of the qualitative display is shown in Fig. 1.

On any particular line, as the marker moves along its scale, it changes color; between +/- 5, it is green for "good" values, between 5 and 7 and between -5 and -7 it is blue for "marginal," and at the outer extremes it is red for "danger" or "bad." The variable being plotted is hard-limited so that off-scale values all show in the most extreme position overlaid with a > or < symbol that blinks to attract the eye. If a variable is so far out of limits that it cannot be reasonably scaled, then it is presented in its log base 10 form with the cursor

overlaid with a blinking "?". Thus, the variable will always be visible on the line and the variable's state is always apparent to the operator.

Note that the display format of one quality bar above the other also facilitates rapid interpretation of the state of the entire set of data on the display. If everything is performing within specification, the operator's eye sees the pattern of a vertical column of green cursors. If any single cursor or set of cursors is "out-of-line" it is readily visible. Hence the operator can quickly assess the condition of many diverse data types without exact interpretation of any of them.

IV. An Example

In order to assess the usefulness of the display, an example was programmed into the software supporting the Metric Data Display (MDA), the DSN subsystem which acquires and processes tracking data. Although the display is general and easily implemented on any computer system, the specific example to be examined was programmed on the Modcomp II used as the processor for the MDA.

The variables to be displayed usually have predicted values and tolerances associated with them. To create the display, the variables are first biased so the predicted value will appear at the 0 position on the line and multiplied by a scale factor derived from the tolerance so that the values that are within the tolerance will appear in the middle 50% of the line. The scaled value determines the cursor position. If the value is in the range -10 to +10, the cursor is placed in one of the 21 available character positions on the line. If the value is greater than 10 or less than -10, the cursor is placed at the extreme of the line with a flashing ">" or "<" symbol as appropriate.

If the absolute value exceeds a certain value, recall that its logarithmic representation is presented. For the Modcomp, the maximum integer value is 32767; hence that is the selected limit. If the variable exceeds that value, the line cursor is overlaid with a flashing question mark and the integer part of the exponent is used to position the cursor.

A general-purpose Modcomp II qualitative display subroutine was written and has been tested in the MDA. The subroutine, named QMD, first resets the current DSN display terminal, a Megadata, to put it into a known state. Next, the characters which create the lines are formatted and sent to the terminal. Any line that represents a variable is sent in four parts: the label field with appropriate scaling information; the marker in its appropriate position and with the flashing "?", ">", or "<" overlays; the numerical value of the variable; and the key to a more detailed display. On successive displays, the new marker position is computed and compared against the

old position, and if the marker need not be moved, only the numerical value is updated.

The Fortran program for the Qualitative Monitor Display was developed in two main phases. The first was to establish the exact control sequences needed to command the various Megadata functions, and then to test several alternative schemes for making the line and marker. Various strategies for handling labels and scaling were tried. This phase was performed in the Section 338 laboratory using any of the several Modcomp II machines.

The next phase was to incorporate the features of the QMD in an overlay to be called by the MDA operational program. This necessitated adding QMD to the list of allowable directives, modifying the executive routine so that it would call the appropriate overlay and cataloging the QMD overlay into the load module.

The specific display used to test the QMD concept, shown in Fig. 2, combined variables from two frequently used MDA displays; doppler residuals and pseudo-DRVID were extracted from the appropriate data base. All values were scaled appropriate to their expected values. During tuning operations, however, the doppler residual could be very large. The logarithmic display feature, however, allows the observer to make use of

the cursor position, even though it is far off scale, to adjust the received frequency appropriately to "zero" the residual.

The developmental version of the MDA program has been extensively tested in the DSN Data Systems Section lab, on the MDA at CTA 21, and it is expected to be taken to Goldstone for real-life testing.

V. Results and Conclusion

The display has been demonstrated to a broad spectrum of potential DSN users. The comments received have been very encouraging and the authors expect to see the display used for various subsystems in the DSN's Mark IVA (Networks Consolidation) upgrade. DSN consultants in the area of the human interface have reviewed the display and were very pleased with the concept in terms of rapid and concise interpretation of information.

The qualitative monitor technique can be a useful one for the DSN, particularly for monitor and control. The monitor and control operator must observe many data values from many different pieces of equipment and usually in different formats and ranges of values. The qualitative monitor offers a concise and consistent means to observe station operation.

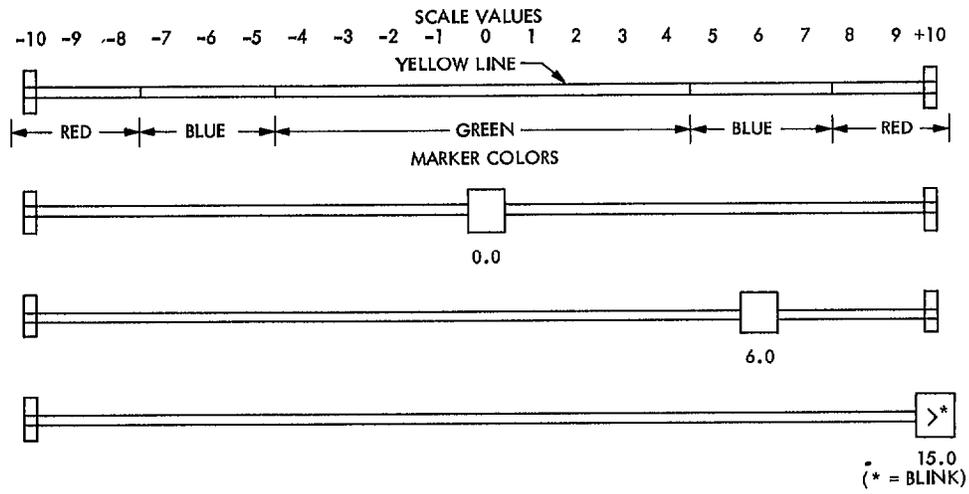


Fig. 1. Qualitative Monitor details

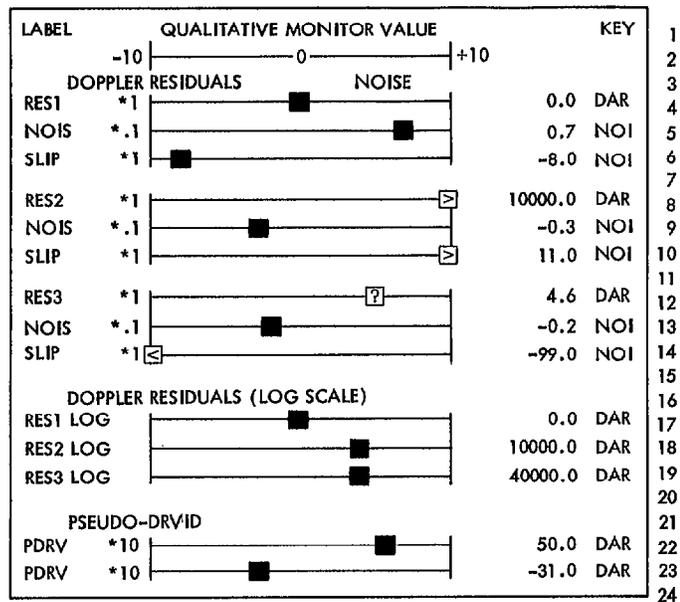


Fig. 2. Qualitative Monitor Display for MDA