Processing For Improved Operator Performance

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RÉSUMÉ

IBM a développé un système de distribution en couleur de résolution haute avec moteurs graphiques d'haute puissance pour la Marine des États-Unis. En support de cet effort, IBM effectu des études pour la démonstration des méthodes améliorées de la présentation des données utilisant une nouvelle technologie de distribution. Des améliorations measurées à 2dB ont été réalisées dans la probabilité de détection à un taux fixe de faux signaux en utilisant la couleur pour ajouter des donées de taux a l'image de distribution ainsi donnant un degré supplementaire d'exemption. Le temps measuré pour trouver un objectif a été aussi reduit à un niveau important. Une amélioration supplementaire à l'image de distribution basée sur la théorie de détection a offert un algorithme traitant l'image relativement simple qui emploi la tradution pièce par pièce et l'integration pour le progrès continuel de la performance. Cette thèse décrit les traitements employés et présent les résultats des experiences courantes réalisées pour évaluer quantitativement les progrès.

ABSTRACT

IBM has developed a high resolution, color display system with high powered graphics engines for the U.S. NAVY. In support of this effort, IBM is conducting studies to demonstrate improved methods of presenting sensor data utilizing new display technologies. Measured improvements of 2 dB have been made in detection probability at a fixed false alarm rate, by using color to add rate information to the displayed image thus providing an extra degree of freedom. The measured time to find a target was also significantly reduced. An additional enhancement to the displayed image based upon detection theory, yielded a relatively simple image processing algorithm that employs piece-wise translation and integration to further improve performance. This paper outlines the processing employed and presents results of measurements made to date to quantify the improvements.

INTRODUCTION

This paper presents a color use strategy for active and passive sonar detection displays using luminance and hue of saturated colors. Color displays provide for an added degree of freedom to the conveyed raster information thus improving the B-scan performance over the monochrome presentations. This strategy requires workstation display consoles capable of at least 64 concurrent colors.

The technique has been applied to the development of multi-hue, color sonar displays for a multi-beam sonar with luminance for Signal-to-Noise Ratio (SNR) and hue for rate from a classic monochrome presentation of the same information. Forced choice test results with operators have been obtained for both the monochrome and multicolor versions of the detection displays. Sonar contacts within 3 dB of the Minimum Detectable SNR (MDSNR) were inserted in the simulated data. The results support the expected 1.5 dB improvement in detection performance for the color versions of the displays with the extra degree of freedom (rate estimate). The time to "mark" a detection from a fixed presentation of the information was also reduced.

The Enhanced Passive Image Processing technique was developed to match the performance of lower resolution displays of passive sonar information to those with higher resolution. This technique mimics the rotation and compression procedure used by operators to review "paper gram" displays. The rotation becomes an adjustable offset of each row of raster data to align target information in a single column of the displayed information prior to applying an adjustable compression of the rows of information. The latter is accomplished by averaging elements in each column over a varying number of rows. The results are presented to the operator in a window on the display. The resulting presentation enables operators to find targets not detectable in the original presentation but found in current systems only by a review of hardcopy data.

Detection Displays For Active Sonar

Detection displays for active sonar and radar typically employ B-Scans with SNR as luminance levels. Figure 1 shows a diagram of such a display of SNR drawn as a function of range (time), and bearing. Range zero is at the bottom and increases along the vertical axis, and bearing is
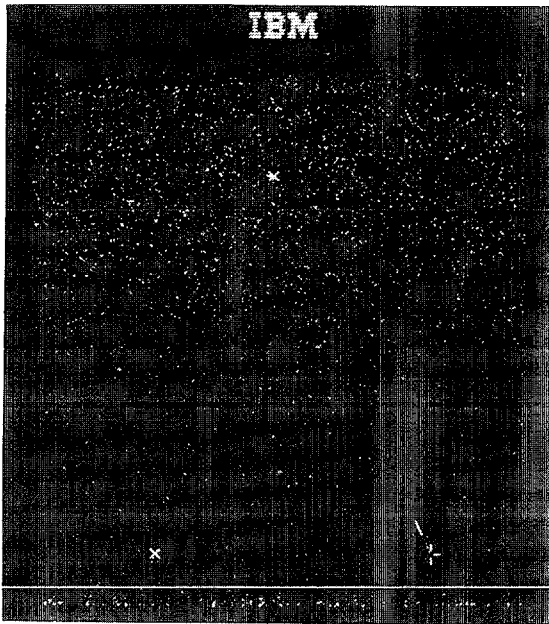
Figure 1. A Typical Active Sonar Display. This B-Scan display of raw data shows SNR, luminance levels, as a function of range, Y (vertical axis) and bearing, X (horizontal axis).

along the horizontal axis. These displays sometimes employ multiple columns of history waterfalling from right to left to enhance detection. High bearing resolution, high range resolution displays with multiple ping histories tax the display capabilities of current CRT technology. Pixel size cannot be made too small or the operator would not perceive the luminance level. Adding another dimension would be difficult or impractical on a monochrome display. Modern sonars and radars typically provide Doppler (range rate). It is made available to the operator as a cursor selected parameter and therefore cannot support the initial visual search for the target despite the fact that Doppler is an

important discriminator against false targets. A color CRT can provide this added information in the initial presentation without requiring additional surface area on the display.

After a review of attempts at color in the past, three rules were formulated to preserve performance. The first rule is to retain luminance as the SNR parameter in the presentation. Image processing algorithms used to prepare the pixel information are retained and the format left intact to maximize the benefit of prior experience and operator training. The second is to use saturated colors only, that is to have only two of the three primary colors—red, green, and blue—in use at any one pixel. This simplifies recognition of hues by the operator and allows a more consistent adjustment of the luminance level of each hue. The third is rule is to force the colors to lie on a continuous path along the edge of the color space. This later monotonic progression allows the association of adjacent range rate estimates (Dopplers) as well as SNR estimates by the operator. Range rate information was distributed from blue for an extreme opening range rate; toward green for zero range rate; and then toward red for a closing range rate. The hue is shifted from blue to greenish blue to bluish green to green, and so on, by dropping the drive level on one primary color and increasing it on another. These rules allowed the observers to rapidly adapt to our color strategy and appeared to make observer performance insensitive to exact color perception. A detection presentation using 64 colors of 8 hues, each at 8 luminance levels, is given in the same format as shown in Figure 1. The lowest levels of marking are all black. The 64-color presentation of Figure 1 is identical to the monochrome version except that the pixels have been color(hue) encoded to present Doppler information. Figure 2 is a table of the relative drive levels "tuned" to the display under test to make the apparent luminance levels for each hue the same.

Hues at Maximum Luminance Levels A(i) = [1 x 8]			Attenuation Values B(j) = [1 x 8]
Index	Red	Green	Blue
1	0.00	0.72	1.00	1.00
2	0.00	0.76	0.84	0.84
3	0.00	0.79	0.71	0.71
4	0.00	0.85	0.00	0.59
5	0.59	0.73	0.00	0.50
6	0.71	0.68	0.00	0.42
7	0.84	0.60	0.00	0.35
8	1.00	0.45	0.00	0.00

Note: Colors, C(i,j) = A(i) x B(j)
All color values normalized

Figure 2. Color Definition for the 64 color display. The 64 colors are defined by taking each element of the 8 hues at their maximum luminance levels and multiplying them by the corresponding attenuation element. These values must be adjusted to match each monitor design.

Detection Results For Active Sonar Displays

Formal testing using a forced choice technique [1] that fixed the false alarm level was done with 20 operators. Operators were told that there were 6 contacts or targets on each of 10 display presentations. They were presented with a pseudo random mix of contact locations, contact range rates, and SNRs that varied within 3 dB of the expected MDSNR. Although each color presentation was matched with a monochrome presentation of the same random data, no one operator saw two displays based on the same data. The measured probability of detection is shown in Figure 3 as a function SNR for all contacts. The observed detection probability at a given SNR was the ratio of correctly identified contacts divided by the total number of contacts at that SNR. A Receiver Operating Characteristic (ROC) curve indicative of the monochrome test conditions was superimposed on the measured data. The improvement of the colored display, the apparent left shift in the ROC curve by 1.5 dB from the monochrome was as expected, reflecting the added degree of freedom that the color Doppler encoding provides.
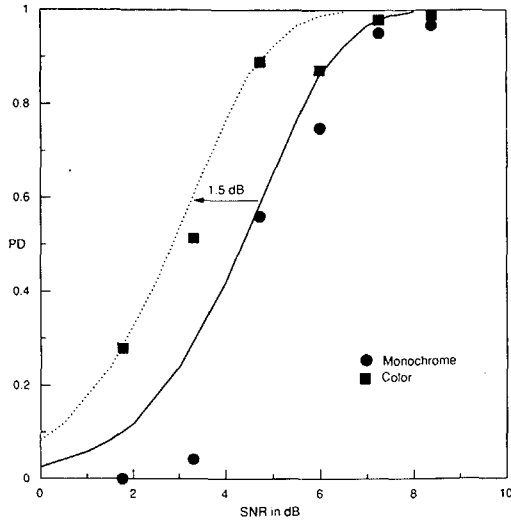
Figure 3. Detection Performance; Color versus Monochrome for Active Displays. This figure shows the measured Probability of Detection (PD) as a function of Excess SNR based upon the predicted monochrome results drawn as the ROC curve. The measured data supports the expected 1.5 dB left shift improvement of the color display.

The time to detect the contacts was also measured. The average detection time per detected contact for the color active display was 26.8 seconds; 7.6 seconds faster than for the monochrome display[2].
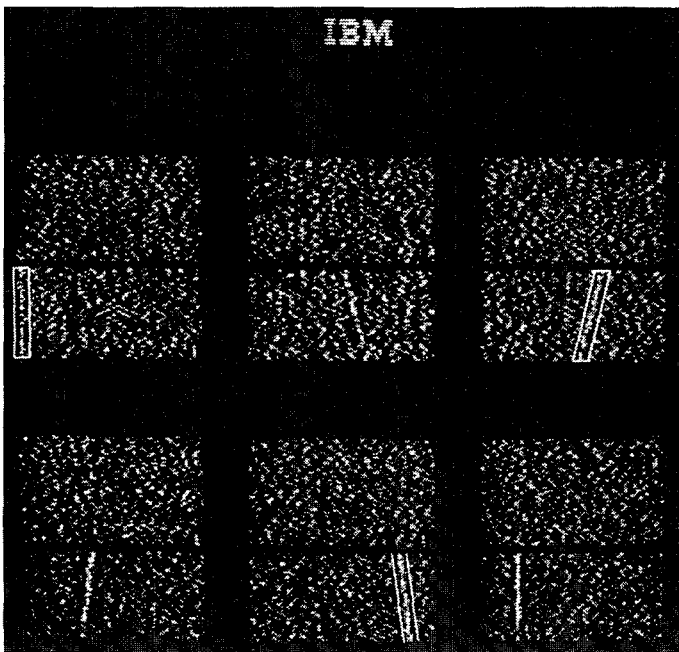

Figure 4. A Typical Passive Sonar Display. This B-Scan display of raw data shows SNR, luminance levels as a function of Time, Y (vertical axis) and bearing, X (horizontal axis).
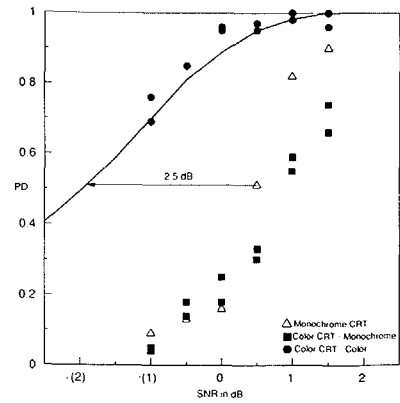

Figure 5. Detection Performance Color versus Monochrome for Passive Displays. This figure shows the measured Probability of Detection (PD) as a function of Excess SNR based upon the predicted color results drawn as the ROC curve. The measured data supports the expected improvement, left shift of the color display measurements.

Detection Displays For Passive Sonar

A typical display for passive sonar is the gram format, a B-scan of either frequency or bearing as a function of time. As in active, SNR is presented as luminance level per pixel. A simulated portion of a passive broadband display is shown in Figure 4.

Contacts or targets on these displays appear as lines of approximately constant bearing rate over the displayed time window. Borrowing a proven technique from automatic detection[3], data is averaged over each of many constant rate hypotheses at each bearing of the newest time line and the highest estimate of average SNR at each bearing is selected as its rate estimate. This rate estimate is a bearing rate for a broadband display. A similar estimate would provide a frequency rate at each frequency for a narrowband passive display. Classical detection theory predicts that the averaged result will improve detection MDSNR by 5 LOG(n), where n is the number of independent post detection time lines averaged. The SNR represented by this average is significantly higher than the SNR of the data on a given line since n is usually greater than 16. This procedure using n greater than 16 also means that the estimated rate is relatively uncorrelated with any luminance level on a single time line. This rate estimate for a passive display is employed using exactly the same strategy as was used for the active display. The detection results for a broadband test is shown in Figure 5. Each operator presentation contained 12 targets within 2 dB of the expected MDSNR. Again the ROC curve shows a shift, approximately 2.5 dB, provided by including rate information. This test was also used to compare a monochrome CRT and a color CRT. It was observed that the shadow mask color CRT display in monochrome did worse than the monochrome CRT. This is thought to be caused by the "blooming" effect with intensity which is more

Figure 6. Piece-wise Translation and Integration for Improved Performance of Low Resolution Images. This sequence illustrates the Enhanced Passive Image Processing technique with the following representations: a)the original image presentation, b)the translated image to vertically align the target data, c)the compressed version with integration or averaging along the vertical to increase the displayed SNR per line of information.
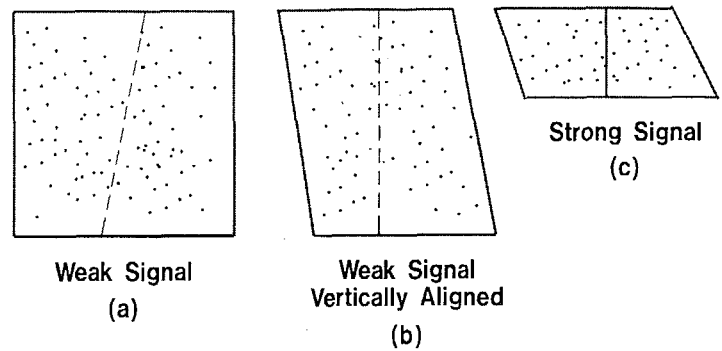
pronounced in a monochrome CRT. This effect tends to enlarge the brighter spots enabling the eye to better associate them. It is next shown that numerical averaging of multiple lines and the presentation of the results on a lower resolution display can compensate for this loss.

Enhanced Passive Image Processing

The Enhanced Passive Image Processing technique was developed to take advantage of the high speed processing power of newer workstations to improve operator performance with passive displays even further. The technique emulates the two axis rotation of "paper grams" done by experienced operators. It improves detectability by compressing or averaging the higher marking levels of a contact or target along the constant rate axis. This technique is also analogous to the automatic detection techniques based upon multi-rate hypotheses [3]. The technique assumes that the raw luminance levels are arranged in rows and columns, where frequency or bearing estimates are arranged monotonically in a given row and the time axis is along the columns. The base of this matrix image can be moved only horizontally to distort the rectangular shape of the original matrix into a parallelogram. Elements of the original matrix defining a contact at a constant rate can be made to align vertically by moving the base of the parallelogram left or right on the screen. Data may then be compressed by averaging along the vertical axis and re-presenting the information. The averaging window is defined by providing the second degree of freedom to the operator controls. The sequence shown in Figure 6 illustrates this process. This image process allows the operator to extract the maximum amount of target information from the display, make the detection of weak targets happen without compromising the time resolution needed to detect sudden rate changes.

Conclusions

It has been shown that color presentation can significantly improve operator detection performance over monochrome presentations by providing a concurrent additional degree of freedom. A contained graphics engine can improve operator performance by compensating for the time/resolution mismatch on a typical detection display which is a compromise between observing dynamics associated with strong targets and detecting weak targets with a constant rate. A 2 dB improvement in detection performance for the extra degree of freedom has been demonstrated. The speed to find contacts using color images was faster than in monochrome. It took operators 25% longer to find targets in monochrome images than it did in color. A simple operator driven image process to compensate for the 3.0 dB spread in detection performance measured for CRTs of different resolution has been defined. These results have demonstrated that modern color workstations can significantly outperform lower cost monochrome display systems.

References

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