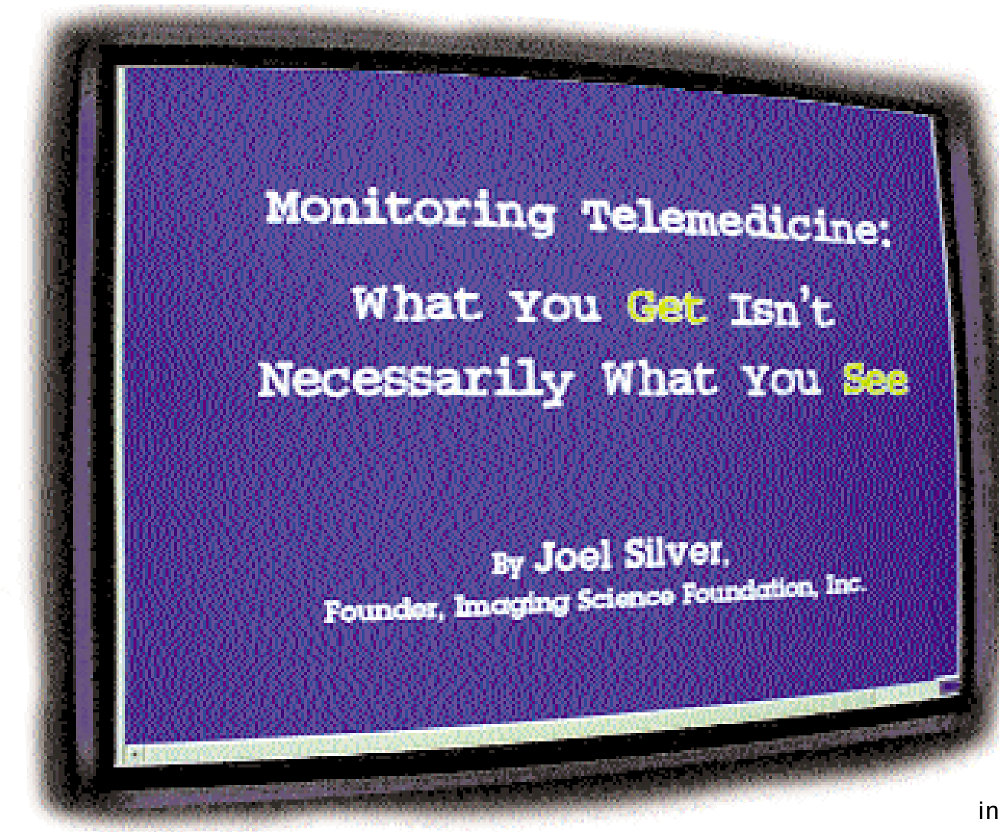


Telemedicine begins and ends with images on electronic display devices.

The ability to deliver an accurate image from any source to any destination must be a primary system goal. Up to this point we have been fixated on moving data more quickly, and on the accuracy of the bitstream we move around. It is now time to pay some attention to how accurately that data is translated into images on the display devices we use every day. It's of little use to the Dr. Smith in Faroff, North Dakota if the X-ray she sent in for a reading to a major medical hospital radiology department is read immediately, but imprecisely. That hairline fracture will still be there, even if the miscalibrated monitor missed it.

Let's look at some very basic issues regarding any system that makes images with electronics, including computer and television functions, both of which are simply electronic imaging environments.

Look at any display of multiple computer monitors or television sets showing the same image. You'll see the identical electronic signal from the identical electronic source reproduced differently on each monitor. You'll see pictures with different colors, brightness and intensity, even though the electronic information creating the pictures came from the same electronic source. Obviously, not all of these display devices are reliable. How do you know which one properly reproduced the incoming electronic information? How do you decide what criteria to use to select the model or brand you will put in your facility? Let's look at some ways of judging accuracy.

Shadow and light: "Black Level" and "Brightness"

In any image, be it live, film, print or electronic, there are portions that are too dark for us to see any meaningful detail. In electronic imaging, we call the level of illumination where shadows become darkness the "black level".

If you look at your computer monitor or television, you will find a control that is normally called "brightness". The function of this control is to set the black level. Put on any picture information and run the control up and down its entire range. You will notice that, when it is turned all the way up, you see information in the dark parts of the image that disappears when you turn it down. Thus, when you set this control, you define where detail is seen or not seen, and, in so doing, you may alter the intentions of the programmer who created the image.

In a dependable communication system, the programmer or technician who creates the image and the viewer who receives the image should be using the same black level setting. But, in order to do that, all users of a system need a reference for the right level of black. In professional video workplaces there are test patterns that provide such a reference. Similar references are essential for accurately generating and displaying medical images.

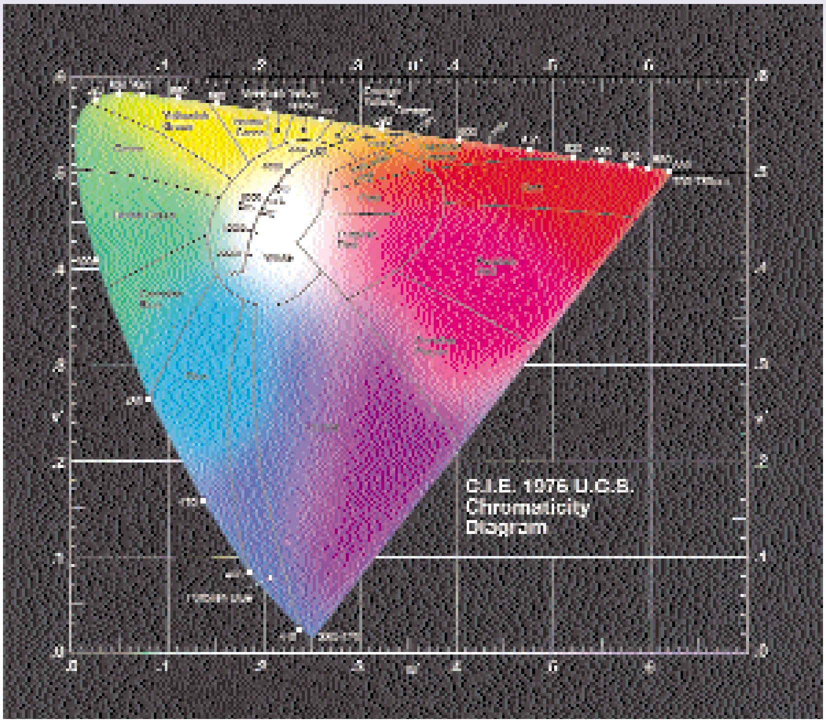
Primary colors:
Not Red, White and Blue but RGB

People only see the colors red, green and blue. Our eyes have rods and cones that are sensitive to those particular colors. Our brains actually calculate the other colors we perceive. All color computer monitors and video devices are machines that output red, green and blue light.

In any RGB communication system, the colors red, green and blue should be the same on both the production and the reproduction devices. But, take a look at the reds on your televisions and computer displays. You will see that they are not consistent. Some reds look far more orange than others. Some greens look more yellowish than others.

Your computer monitors and your television sets are RGB display devices. To be more precise, since they put out waves of visible light, they are analog RGB display devices. Computer monitors are not digital devices. Even HDTV sets will not be digital devices. Display devices are analog links in digital communication systems. No matter if it is a vacuum tube monitor or an LCD panel array, it is an analog device. If it is a monitor, the source of its light is a cathode ray tube (CRT). If it is an LCD array, the source of the light is a light bulb behind the screen. Even the new micromirror devices being marketed as “Digital Light Processing” (DLP) chips by Texas Instruments produce analog information. They may be technomarvels that use micromirrors far too small to be seen, but they produce useful information only when analog light from a light bulb bounces off a mirror. With those digital devices, the surface of the mirror is the digital-to-analog interface. The confusion on this point is widespread. The weak link in

All colors can be defined as coordinates on the Chromaticity Diagram



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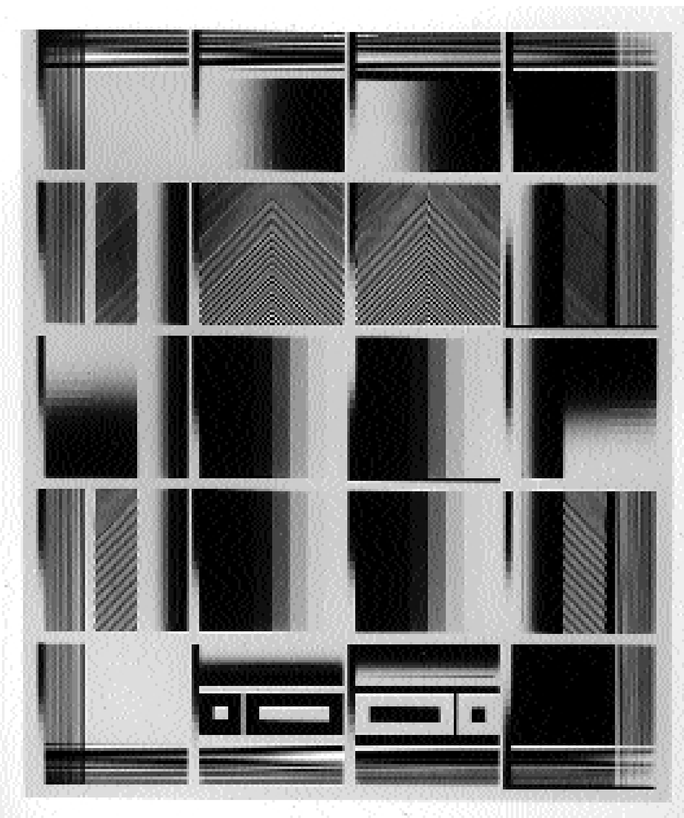
most digital information systems remains the analog displays.

Colors of white

In electronic imaging, we produce white by mixing red, green and blue together. The differences we see in colors of white result primarily from differences in the amount of each primary color we use. We can tint our whites red, green or blue by adding or subtracting minute levels of each primary color. The term "white balance" refers to this balance of primaries. In electronic imaging, we measure the color of white using the Kelvin (K) scale. For example, typical incandescent bulbs produce a yellow or orange color and measure about 1800K to 2200K. Fluorescent bulbs can be from 3000K to 5000K. Daylight ranges from about 5400K to about 6500K.

Imaging Chaos

In our research, we have measured hundreds of computer monitors and television sets. We have found measurements ranging from 4800K to over 16,000K. This is a prime example of the chaos in imaging. If we create an image on a monitor that is biased toward blue and play it back on one biased toward red, we are not sharing the same information. There must be standards for color temperature, and devices must be set to meet those standards. Do not expect any manufacturer to deliver a monitor perfectly adjusted for your facility.



PACS Test Pattern from Nuclear Associates

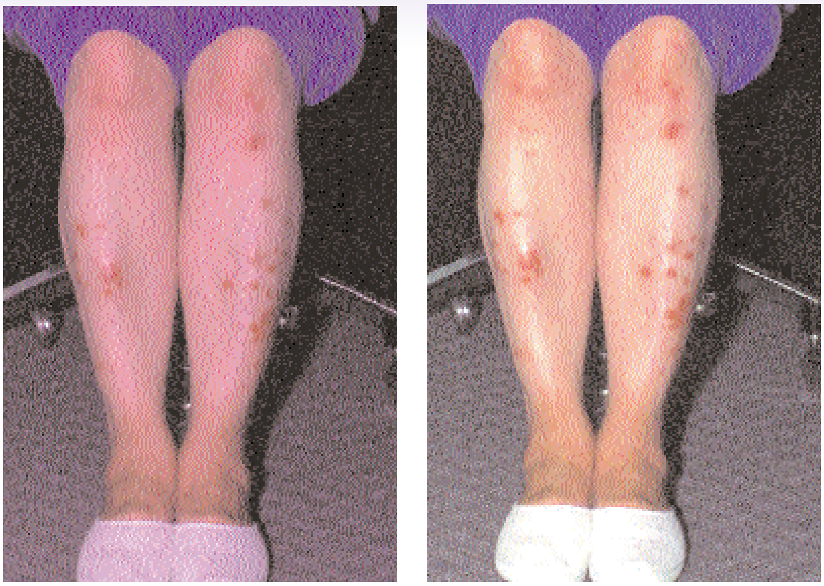
Proper Maintenace for Proper Accuracy

The different environments in which display devices must operate and the different electronics to which they are connected introduce significant variables that cannot be anticipated in manufacturing. Display devices must be calibrated on site with test patterns and instrumentation. A display device should also have the proper controls to be calibrated for use in your specific application. For example, the Sony 1953MD monitor has menu-driven controls allowing six RGB adjustments for color temperature alone. You should also be aware that monitors are also subject to drift as they age. That is not a defect, but is merely the nature of the technology. Like many tools in your workplace, monitors require proper installation and periodic maintenance.

NTSC: Been There, Done That

The problems we have noted with electronic imaging may be newsworthy today, but our government has dealt with these issues in the past. In fact, we can find most of the answers regarding color balance, black level, and the specific colors of red, green and blue in the National

Television Systems Committee (NTSC) developed by the federal government in 1953. Yes, folks, the same system the industry nicknamed "Never Twice the Same Color." But, if we look at the actual system, not its feeble and failed implementation, we see an elegant piece of work that stands up remarkably well even after 45 years. A lot of that work was based on the chromaticity diagram produced by the "Commission Internationale de l'Eclairage" (the International Commission on Illumination) in 1931. The goal of the 1953 system was reliable image transmission. Present-day broadcast television professionals have achieved those goals. Telemedicine professionals can follow the same guidelines.



(Left) Image as received. The red cast obscures the lesions

(Right) Image after RGB adjustment

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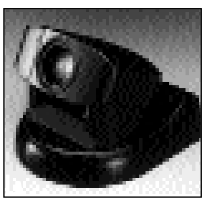

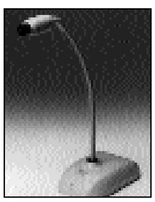

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Telemedicine Should Learn from Broadcast Television

Electronic imaging today is in chaos - with one notable exception. That exception is the professional television industry. In any broadcast, animation, production or post-production facility, you can see row upon row of monitors with pictures that look exactly the same – monitors set up using methods developed by the Society of Motion Picture and Television Engineers (SMPTE). In the late 1980's, an SMPTE committee came up with tools that help make sense of electronic images. One example of those tools is the television test pattern with its vertical bars of color. Today there are readily available test patterns for proper set-up of contrast, brightness, color, tint and sharpness on computer monitors as well. Some of these test patterns are designed for evaluation by the naked eye. Others require instrumentation for proper adjustments. Companies such as Philips, Minolta, Tektronics, Photo Research and Graseby manufacture professional instrumentation and test-pattern generators for calibrating display devices. If your staff has been setting up your monitors by eye or using the factory presets there is undoubtedly room for improvement in the quality of your images.

A telemedicine facility qualifies as a critical viewing environment, certainly more so than your average TV living room. For that reason, display device standards, test patterns and calibration instrumentation must find a place in the distance healthcare industry. With due apologies to Thomas Jefferson, the price we must pay for accurate telemedicine is eternal monitor vigilance.

Joel Silver (561-997-9073; joelsilver@worldnet.att.net) has produced seminars for television professionals for years. You can find technical excerpts from "ICIA Display Standards Seminar" by Joseph J. Kane, Jr. on the Telemedicine Today website: www.telemedtoday.com.

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