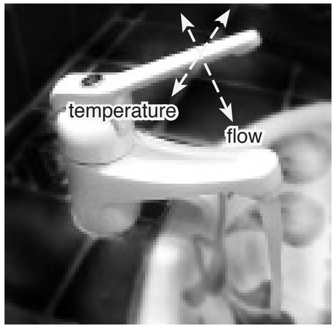
COLOR SPACE

GAMUTS, DITHERING . . . AND EVEN THE KITCHEN SINK*

An explanation by way of analogy.

You're remodeling your kitchen, and picking out a new faucet for the sink. There are lots of styles to choose from, but they're all variations on just a couple of basic designs. Let us help you.

First, let's consider the old-fashioned two-knob job—where one knob controls the flow of hot water, and the second controls the flow of cold water. Traditional. Simple. Proven.



Then there's the newer style, where one fancy lever does it all: you move it up and down to control the flow, and pivot it left and right to control the temperature. Difficult choice, but let's say you choose option one: the two-knob system.

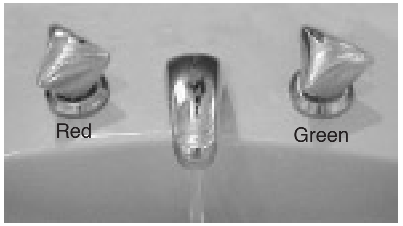
It's a few weeks later. The water's running and you're busy washing some dishes. You couldn't be happier with the flow, but realize it'd be nice to have the water a little warmer. What do you do? Well, there's no Temperature control, per se, which is what you actually need right now. With this style of faucet, your only option is to turn up the hot "component." The water gets warmer, all right, but now you're also using more water than before, and more than you need. So you turn down the cold "component" by about the same amount, and now it's hopefully the temperature you wanted, with roughly the same flow as before. Close enough. With this style of faucet, you have to guess a little, do a little trial and error, and make two adjustments (more Hot, less Cold) rather than the one adjustment you actually needed to make (higher Temperature, but with a constant Flow).

Take two: Let's imagine that you'd gone with the one-armed faucet instead. When you do the (above) washing-dishes test, this one-arm faucet makes the adjustments with ease. Now your task is to fill up a teapot with plain old hot tap water. Of course there's no hot water knob per se, so you lift the lever to get the right amount of water flow, then move it to the left to set the temperature. (If you're really an experienced kitchen pro, you might do all this in one move, but you'd still be making adjustments along two different "axes.")

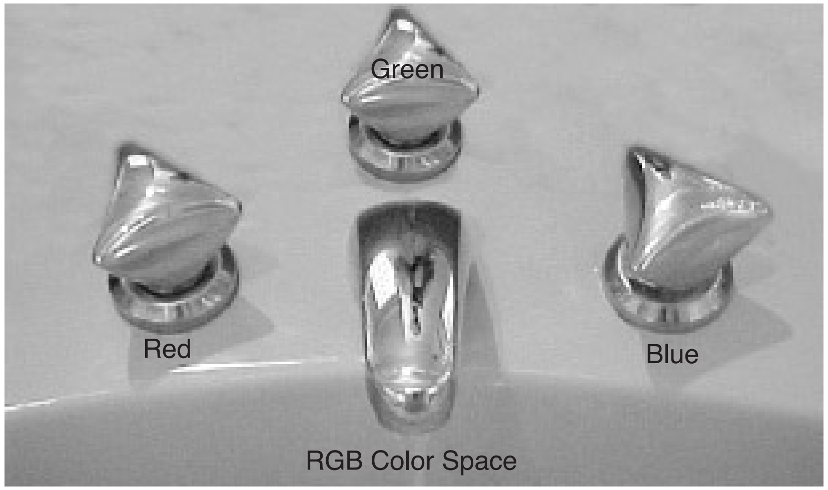
Both types of faucets have the same plumbing "input"—a hot water pipe and a cold water pipe. The difference is the mechanism for controlling the amount of each. Because of their design, each has advantages and disadvantages depending on your fluid needs. We'll come back here in a moment.

*Please don't write to say these photos are bathroom—not kitchen—fixtures.

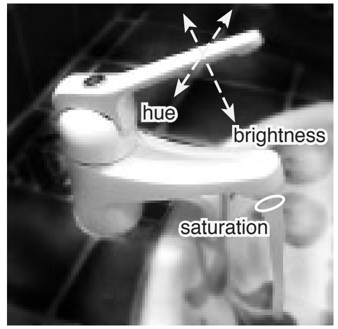
Applied to the world of video, "hot" and "cold" are pure *colors*, and the flow is the intensity of those colors. By mixing them, you create new colors. Each set of faucets represents a specific set of controls for mixing its colors and making *new* colors. The entire range of colors you can make with those particular faucets is the system's "**color space**." What we're doing is controlling the "flow" of red, green and blue light onto a point on a TV screen (but it could also represent the value of that point on an analog or digital videotape, inside a data file, or transmitted via a TV station or streaming Web server). For a specific color, the numbers representing the position of the various "knobs" might be different, depending on the color space being used to represent or transmit it.



Most people do not mix red, green and blue to make new colors. What we do is choose the colors we like and ask a computer to deconstruct that choice into the quantities of red, green and blue that are required to encode it. If you only have faucets for red and green, it is impossible to make BLUE. It can't be done; blue is not in the color space of a red and green world. Likewise, there are many "normal" shades of colors that cannot be described in simple terms of red, green or blue; these shades are outside the RGB color space. Every color space is a different "language" or "dialect" for communicating information about color. When you graph those color spaces, the axes reflect this dialect.



Where life gets complicated is that, while similar in many respects, the color space made by mixing red, green and blue is not the same is the one you get by mixing Luminance (Y), R–Y (C*r*) and B–Y (C*b*). And sometimes the controls you have for adjusting color are in one space, but the output you need is in another. For example, an editor often needs to get a certain output on a professional video deck, but the knobs that control the color are for set-up (black level), video (white level), chroma (color saturation) and hue.

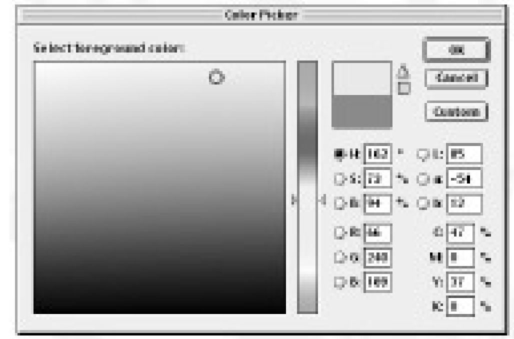


Timebase corrector controls (left) provide an editor with knobs for adjusting hue, chroma, etc.; the output from the video deck (right), however, offers component, composite and S-video—each within its own color space.

Or we might be tweaking the picture on a TV set, which receives a signal as YIQ, and displays it as RGB, but lets us adjust it with the more user-friendly *brightness*, *contrast*, *saturation* and *tint*. Or perhaps we're creating a graphic image on a computer screen, and using HSB (hue/saturation/brightness) or even a "crayon" color picker to choose values for an RGB-displayed image or a CMYK printout. All of these translations of one color space into another are riddled with potential problems.

When it's necessary for us to make the conversion of a video signal from one color space into another (like feeding the output of a component VTR into a capture card that only "understands" RGB), we can use a small converter box called a *video transcoder*. You may actually be doing that conversion already, with-

A typical breakout box (this, from Media 100 circa 1995), with balanced audio in/out on the left, component video in/out on the right, and composite in/out nestled between.

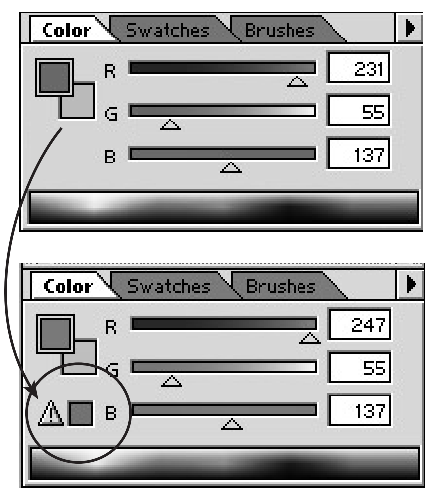


A typical format for a software color picker (this, from Photoshop), where colors picked on the left are represented on the right in different color spaces: H-S-B, R-G-B, L-a-b, C-M-Y-K.

out knowing it—say, using an editing system with a "breakout" connector box that has inputs for a number of formats (including analog component, composite, and S-VHS). In that case, the transcoding is done by circuitry in the capture card, or even in the breakout box itself (actually the ideal place, since there's less noise and interference there as compared to putting the converters inside the chaotic electrical environment of the computer itself).

Let's go back to the second faucet analogy (from page 130), and say that the lever isn't perfect: moving the temperature lever fully to the left gives us mostly hot water, but doesn't close the cold water valve completely; and moving it fully right gives us mostly cold water, but still lets a tiny bit of hot water through. If it were important for us to have purely hot or purely cold water, we'd have been better off using the old-fashioned hot-and-cold style faucet knobs, since they let us block off either supply completely just by not turning on that knob. Each style of faucet therefore gives us a slightly different range of temperature choices.

GAMUT WARNING



In the world of video and color, that range of choices available to us in a particular color space is called its **gamut**. RGB color space, for example, provides a greater gamut of colors than can be conveyed by the YIQ color space used in NTSC television. Graphic designers, for example, will find this to be a problem because they have a greater palette of colors available to them on their RGB computer screens and graphics applications than can actually be transmitted to the viewer's TV. That can be frus-

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