The zone system and digital prints

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Figure 1: London Tract Church

1 Introduction

Magazines and publishers have been printing digitally for years. They use high end drum scanners, and expensive printers well outside the price range of the ordinary photographer; however, new technology has made it possible for anyone to make digital prints with a modest investment. Reasonably priced scanners are widely available as are desktop photographic quality printers. The desktop printers are very good when properly used, and can produce prints indistinguishable to the eye from those made in the darkroom. Unfortunately, they fade rapidly, but it is a simple matter to send a scanned image to a commercial shop for printing using , say, a LightJet 5000 with paper such as Fuji Chrystal Archive. Such prints by all tests, appear to last at least as long as Cibachromes made in the darkroom. The fading is serious with respect to color; however, black and white prints from desktop printers should last considerably longer, but since ink is used, probably not as long as conventional prints.

The richness offered by digital is such that it surely will become part of ordinary technique. For who among us has not grieved over an errant telephone line, an unexpected color cast, or a flare where none should be. Digital can correct these things with ease. The craft is full of uncertainties which defy our art and sometimes make an image less than our visualization. Some can be fixed in the darkroom, some cannot. It is to this second group that digital manipulation offers opportunities.

Black and white photography remains important, and elegant photographs are still being produced. For this, the Zone System is a fundamental part of the photographer's craft (Adams 1981). It is a systematic methodology designed to produce photographs which match the photographer's visualization. Almost all of the ideas carry forward to digital prints, but there are one or two wrinkles that require study.

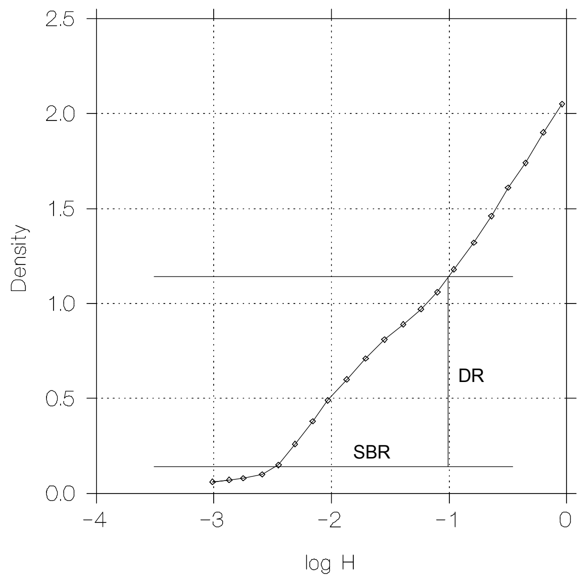

Figure 2: Characteristic curve for TMax, using TMax RS developer for 16 min.

The central part of The Zone System is the adjustment of contrast by varying processing conditions. To do this, one must establish a relationship between the range of luminances in a scene and the processing conditions so that a long range may be compressed to fit the printing range and a short range expanded. Figure (2) shows a characteristic curve obtained for TMax, developed in TMax RS for 16 minutes. The *DR* vertical distance is the range of densities that may be printed, and the *SBR* is the corresponding range of subject luminances in the scene. The designation *SBR* is due to Davis (1999), and I will assume that the reader is familiar with his work. In this case, the range of usable exposures is from about -2.5 to about -1, or about 1.5. This may be translated into stops by dividing by 0.3 to obtain 5 stops. In this case a scene with a 5 stop range will produce a negative spanning the range of a print when the negative is developed for 16 minutes.

Similar curves may be made for other developing times, allowing the photographer to choose processing conditions based on the range of luminances in the scene.

This procedure can be applied directly to digital printing, requiring only the input of the proper DR. However, since the negative or transparency will be scanned as part of the process, the question naturally arises as to whether or not one cannot use a scanner instead of a densitometer? It is the purpose of this article to discuss this matter.

2 Scans and densities

Scanners are similar to densitometers, but since their output is digital, the transmitted light is coded into a range of numbers. The usual range comprises 256 values running from 0 through 255, with 255 light and 0 dark. The process is shown in figure (3). The lower right quadrant of this figure shows the scene translation into density by a film whose characteristic curve has a gamma of 0.75, such as might be obtained for a contrasty scene. (The scene illumination is scaled with respect to the speed point.) A scanner shines a light trough the negative, and the second quadrant at the lower left shows the translation of this according into the transmittance scale running from 0 to 1. A scanner codes the transmitted light to the 256 value scale and further codes it using a curve with a gamma of 0.45. This is shown in the third quadrant at the upper left. The principal reason for using the gamma 0.45 curve is to compensate for the nonlinearity in the video. Video response to input voltage is well described by a curve with a gamma near 2.5. PC monitors use 2.2, and Macintosh's use 1.8. For a PC monitor, applying a an inverse curve with gamma 0.45 adjusts for this physical phenomenon by modifying the data before it is sent to the video. The video response is shown in the fourth quadrant at the top right.

This is theory. In practice scanners may not use a gamma of 2.2. The actual value needs to be determined by experiment. The Nikon LS-4500AF which was used to produce the data in this paper seems to use a value of about 1.6.

If one scans a negative produced by a step tablet, one may read the 256 coded values in a program such as Photoshop, and it is possible to arithmetically undo the coding and approximate the densities that were read by a densitometer. The formula is $D = -\log(S^{1/\gamma})$, where γ is the gamma used by the scanner, D is density and $255S$ is the output read from the RGB info panel in Photoshop. Figure (4) shows plot of densitometer values against densities obtained from a scan on the Nikon LS-4500AF. Figure (5) shows the densities overlaid. The agreement is quite good, except at the upper end.

The discrepancy at the upper end is due to coding into the 256 step range. Large densities correspond to small transmittences which code into small integers on a 256 step scale, and the precise recovery of the original density from such integers is not possible. The discrepancy is of little importance, since it appears well above the range of usable densities.

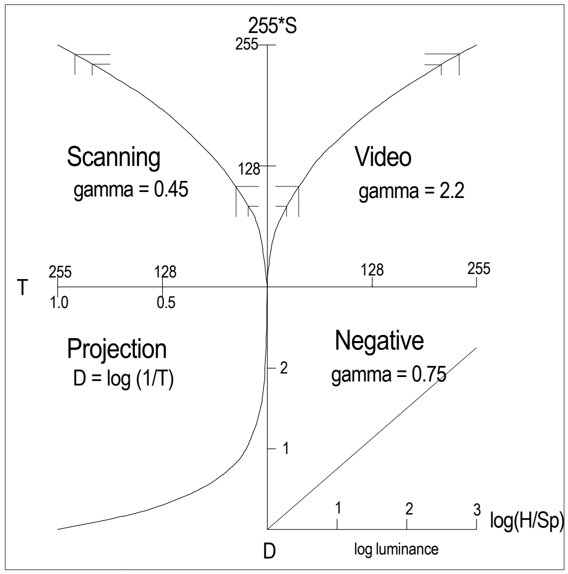

Figure 3: From subject to video output

3 Positive images

The software in many scanners will invert the negative image, and for those that do not, it is possible to invert it in Photoshop. The formula relating density to the value output from a positive image is $D = -\log(1-P^{1/\gamma})$, where $255P$ is the output read from the RGB info panel in Photoshop for a positive image. Figure (6) shows a the readings for a set of positive images of TMax 100 developed in TMax RS developer for the times indicated. Horizontal lines have been drawn at 45 and 225 to indicate IDmin and IDmax. The IDmin corresponds to 0.1 density above base plus fog, and the IDmax corresponds in this case to a density of about 1.1. The IDmin was calculated, but the IDmax was obtained by inspection. In actuality, both are apparent from an examination of on-screen images – different observers may differ slightly, but not seriously in their determinations of these points.

There are three parameters that are usually estimated from plots of characteristic curves in The Zone System: (1) film speed, (2) subject luminance range, SBR, and (3) gamma. All may be obtained from the positive image.

ASA film speed is defined as 0.8/H, where H is the exposure necessary to produce a density of 0.1 greater than background and fog; i.e., IDmin. Figure 6 gives the ASA speeds 214, 200, 188, 150, and 125 for development times from 16 minutes to 4 minutes. These are essentially the same values that may be obtained from densitometer readings. The IDmin line in figure 6 is drawn as a horizontal line. It might be drawn with a slight slope to account for the fact that the background and fog levels decrease slightly as development time decreases.

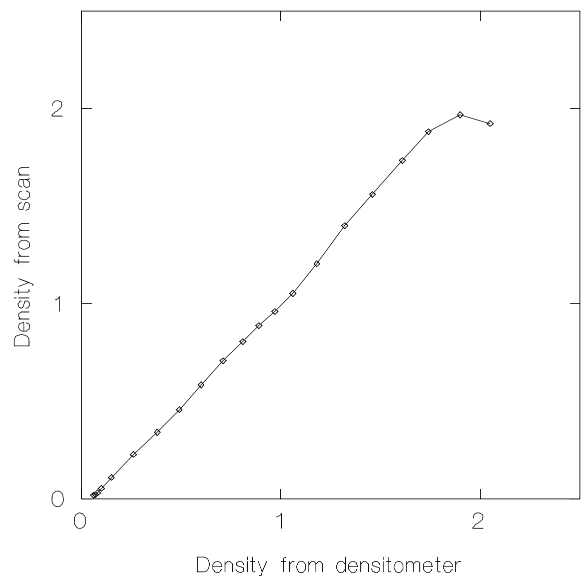

Figure 4: Density from scan verses densitometer values.

One might also take camera flare into account as Davis (1999) recommends. These are quite minor changes that have little practical impact.

The SBR may be obtained just as for a density curve, since it represents the distance in log H between the crossing of a curve and the IDmin and IDmax lines. The SBR's for figure (6) in stops are 3.1, 4, 4.3, 5.6, and 6.2. They are of course the same values that would be obtained from a density curve using the IDmins and IDmaxs.

The positive curve flattens abruptly above IDmax, which is quite different from the behavior of a density curve. This simply reflects the fact that there is little information above IDmax. The slope of the positive curve between IDmin and IDmax indicates a fairly uniform gradation in tones. It is a mathematical fact that the average of the slopes at each point of a curve between IDmin and IDmax is given by the ratio of the distances as illustrated in figure (6): this is the average gamma. Because of the difference in scale, this average gamma will differ from that for a density curve.

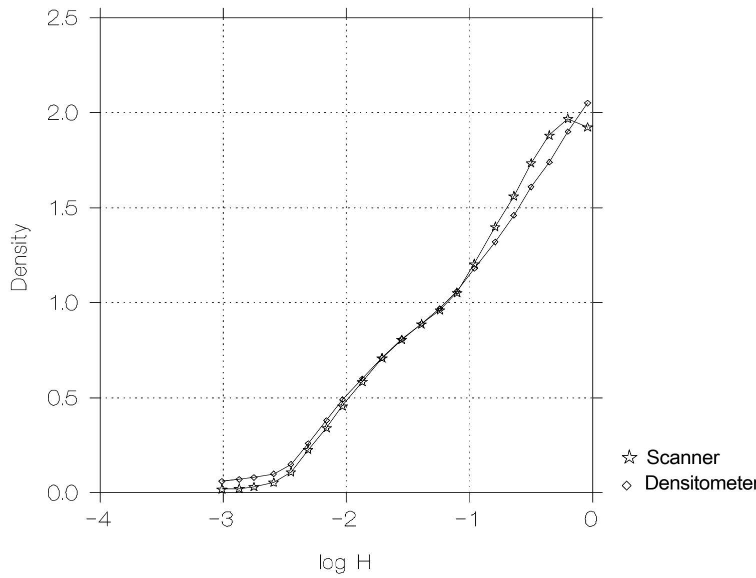

Figure 5: Overlaid densities from scanner and densitometer.

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2. Davis, Phil (1999) Beyond the zone system, Focal Press, Boston.

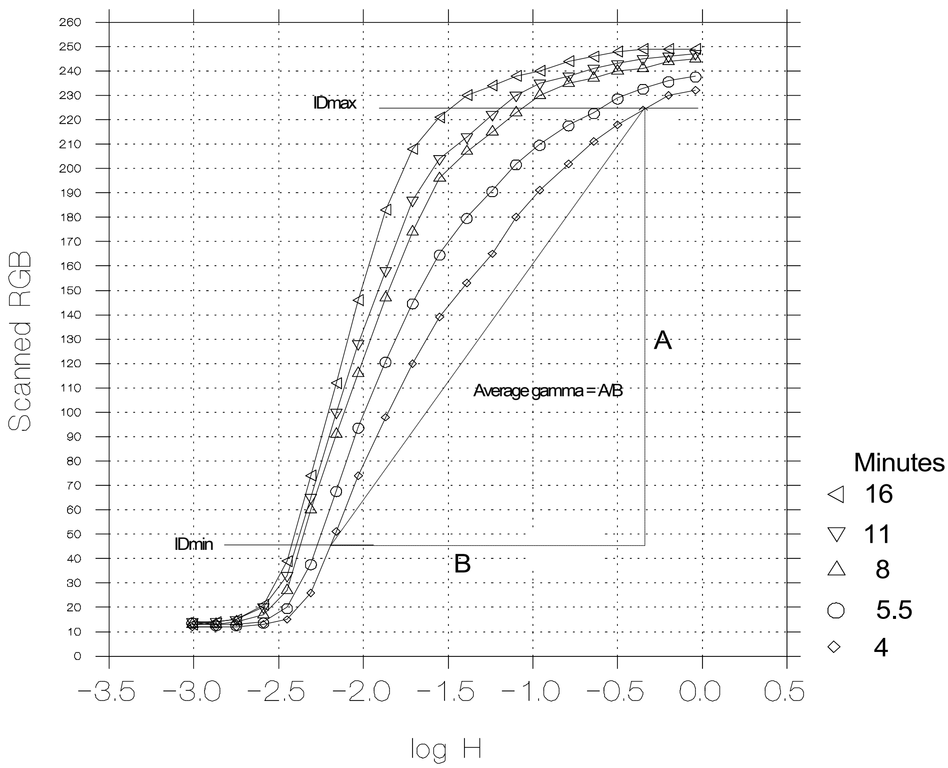

Figure 6: Positive scans for 5 development times