Altering Grayscale Images to Compensate for Press Fingerprints

by Jerry Waite

Grayscale images are generally made from black-and-white or color continuous-tone photographs. Original photographs are digitized using one of a number of scanning techniques—ranging from desktop scanners to Kodak PhotoCD equipment—and saved as computer files. Saved digital files can then be opened directly by page layout programs, such as Adobe PageMaker or QuarkXPress, placed in the desired position on a page, and then output to laser printers, imagesetters, platesetters, or digital on-demand printing equipment.

Unfortunately, grayscale images placed directly into page layout programs will probably look terrible when printed on a printing press because such images have not been altered to compensate for the effects caused by the printing process. In particular, each printing process—indeed each printing machine—causes two types of changes to the grayscale image: tone range compression and halftone dot deformation. To produce the best possible reproduction of grayscale images, it is necessary to determine the actual effect of a particular printing press on tone range compression and halftone dot deformation through careful testing. Upon completion of these tests, the unique characteristics of a press, known as its fingerprint, are recorded. The fingerprint can then be used, in conjunction with image editing software such as Adobe Photoshop, to match a given photograph to the particular press. Matching a photograph to a particular press' fingerprint will result in the best possible reproduction of a grayscale image.

This paper will describe the variables affecting tone range compression and halftone dot deformation, describe a method for fingerprinting an individual press, then explain how Adobe Photoshop can be used to match a grayscale image to a particular fingerprint.

Variables Affecting Tone Range Compression and Halftone Dot Deformation

Copy Density Range

Original continuous tone photographs are composed of thousands of varying tones ranging from white to black. Each tone can be described in terms of its density, or darkness. The density value of any tone can be measured numerically using a special instrument called a densitometer. White tones are not very dark, so they have low density numbers near zero. Conversely, black tones are very dark, so they have high density values—2.00, for example. Middle gray tones have density values around 0.60–0.90. For a more complete explanation of density and the mathematics used to derive density values, see Adams, Faux, and Rieber (1996).

When reproducing a continuous tone photograph, two specific tones must be considered. These are the highlight and shadow. The highlight is the lightest tone in the original, and typically has a density value about 0.10. The shadow is the blackest area. Black-and-white continuous tone photographs usually have a shadow that measures 1.80–2.00. The shadow density value of color originals is usually greater than that of black-and-white originals. The copy density range is the difference between the shadow density and the highlight density, and is calculated by subtracting the density of the highlight from the density of the shadow. By way of example, most black-and-white continuous tone photographs have copy density ranges of approximately 1.70 or higher.

Compression of Copy Density Range Due to Ink and Paper Densities

Black-and-white continuous tone photographs are generally reproduced with a printing press using black ink on white paper. The densities of white paper and black ink can be measured with a densitometer. For example, the white paper specified for a particular job may have a density of 0.15, while a solid single layer of black ink on that paper may measure 1.60. In this example, the maximum printed density range for this paper and ink combination is 1.45 (1.60–0.15). In almost all cases, the maximum printed density range will be less than the copy density range of the original—in many cases it will be much less. Because the maximum printed density range is almost always smaller than the copy density range, the copy density range of the original must be compressed to match the maximum printed density. Consequently, printed reproductions of photographs will almost always have darker highlights and lighter shadows than original continuous tone photographs.

Halftones

Printing presses are not capable of reproducing the thousands of varying shades that exist in an original continuous tone photograph. Instead, a press is only able to transfer whatever color of ink is on its rollers to the paper or leave the paper blank. The varying tones in an original photograph are simulated though the use of varying sizes of halftone dots. Light tones in an original continuous tone photograph are simulated by using small halftone dots, while dark tones are simulated with large halftone dots. Gray tones are reproduced with halftone dots that are checkerboard in shape.

Halftone dots are described in terms of the number of dots per linear inch (lines per inch, or lpi) and the percent of the paper that the dots cover. Therefore, if there are 133 dots per linear inch and a particular dot covers 20% of the paper, that dot is known as a 133 lpi 20% dot. Generally speaking, the higher the lpi, the more pleasing the printed halftone. In most cases, dues to aesthetic and technical reasons, printed halftones should not have areas that are free from dots in the highlights—unprinted paper—or areas that are covered with a solid layer of ink in the shadows.

Compression of Copy Density Range Due to Halftone Characteristics

Printing halftone dots on paper obviously increases the perceived density of the paper. For example, if the density of blank white paper is 0.15, an area covered by 10% dots could measure about 0.20. Similarly, because the shadow areas of a photograph should always contain dots rather than be printed solid, the perceived density of the shadow will be less than the density of a solid layer of black ink. Thus, if the density of solid black ink is 1.35, the perceived density of a halftone shadow could be about 1.30. Because highlights are darkened and shadows lightened by halftone dots, the achievable printed density range of a printed photograph will be less than the maximum printed density range that a combination of ink and paper can produce. Thus, the copy density range must be further compressed.

Determining Smallest Highlight and Largest Shadow Dots

Because the maximum printed density range is almost always less than copy density range, it is very important to limit further tone compression caused by halftoning. To cause the least possible additional tone compression, the smallest consistently printable halftone dot is generally positioned in the highlight while the largest consistently printable halftone dot is positioned in the shadow. Positioning of the smallest and largest printable halftone dot in the highlight or shadow, respectively, was traditionally accomplished through photographic exposures. Today, the same process is accomplished digitally using an image editing program such as Adobe Photoshop.

Before appropriately-sized halftone dots can be positioned in the highlight and shadow, the largest and smallest printable dot sizes must be identified. Two factors are important in specifying minimum and maximum dot sizes: 1) What lpi is to be used to reproduce the photograph? and 2) What are the smallest and largest consistently printable percent dot sizes that can be printed using the chosen lpi? Four variables affect the answers to these questions: 1) the paper or other substrate; 2) the printing process; 3) the characteristics of the individual printing machine; and 4) the client's choice of lpi.

There are two broad categories of paper: 1) uncoated; and 2) coated. Uncoated paper consists of woven wood or other plant fibers. Uncoated papers are generally fairly rough—they have indentations between the individual fibers—and are highly absorbent. Because uncoated papers are rough, it is hard to print extremely small highlight dots on them—such small dots get lost in the indentations. Because uncoated papers are highly absorbent, it is hard to print large shadow dots—the paper absorbs the ink too fast, causing the dots to expand or blot. Such expanded dots overlap one another and appear solid. Coated paper is uncoated paper that has been covered with a protective layer of clay. Coated papers are smoother and much less absorbent than uncoated papers. Because they are smooth, small highlight dots are possible. Because they are less absorbent, large shadow dots can be effectively printed. In general, coated papers can handle higher lpi's, smaller highlight dots, and larger shadow dots than uncoated papers. Thus, the copy density range of the original continuous tone photograph need not be compressed as much when coated papers are used as compared to the compression necessary when uncoated papers are specified.

Many products are printed on substrates other than paper. For example, many screen-printed products are printed on textiles while many products are printed by flexography on plastic film. Each substrate will affect the optimum lpi and printable highlight and shadow dot sizes. In general, however, the smoother the substrate, the higher the lpi, smaller the printable highlight dot size, and larger the maximum shadow dot size.

The printing process—in particular, the type of plate used by the process—impacts the maximum lpi and printable highlight and shadow dot sizes. In general, printing processes that use rigid plates are capable of producing smaller dots than processes that use softer plates. Among the commonly used processes, offset lithography and gravure have the most rigid plates and can produce the smallest lpi screens with the smallest highlight and largest shadow dots. Both flexography and screen printing use flexible plates. Neither process can print high lpi screens or extremely small highlight or large shadow dots.

Within each printing process, every printing machine has its own characteristics. These characteristics depend on the quality of the engineering used in the design and manufacturing of the machine and how well it has been maintained. Within each process, a well engineered and well maintained press will produce higher lpi's, smaller highlight dots, and larger shadow dots. Worn out or poorly designed presses cannot do as well. An often overlooked variable is the skill and carefulness of the press operator. Skilled and careful operators can often coax better halftones out of a worn out press than sloppy or poorly instructed operators can produce on a new machine.

The lpi chosen for a particular halftone can affect the smallest printable highlight and largest printable shadow dots. No matter what the percent size of a halftone dot, a lower lpi dot will be larger than a higher lpi dot. Therefore, even if uncoated paper or other rough substrate is used, small highlight and large shadow dots can be printed if low lpi screens are used. For example, in screen printing it is possible to print a 50 lpi 3% highlight dot on rough textile because the 50 lpi dots are quite large and can span the crevices between the fibers. However, if the lpi is increased to 85, screen printing can handle only about a 5% highlight dot, even on smooth surfaces.

The individual substrate, printing process, and printing machine used for a particular job will impact the lpi and printable highlight and shadow

Process/Substrate	LPI Range	Smallest Highlight	Largest Shadow
Screen printing on textiles	50	3	95
Screen printing - smooth surfaces	85-110	5	92
Flexography - all substrates	85-110	2	80
Offset lithography - coated paper	150-250	2	95
Offset lithography - uncoated paper	120-133	10	90
Gravure - coated paper	150-200	3	98
Gravure - uncoated paper	150-200	5	90

Table 1. Examples of LPI's, smallest highlight, and largest shadow dots for selected printing processes (See Note i)

dot sizes. For this reason, it is important to determine the optimum specifications for each commonly-used combination of these factors through careful testing of the press. However, in the absence of actual test data, rules of thumb for lpi and smallest halftone and largest shadow dot sizes are given in Table 1. It is important that to understand that the use of Table 1 for particular jobs is comparable to attempting to heal oneself using a medical encyclopedia—unless someone who knows what they're doing runs some tests, the strategy is just a guess!

Clients obviously have an interest in the choice of lpi used to reproduce their photographs. Unfortunately, clients often specify lpi screens that are too high for a given process/substrate combination. For this reason, it is the printer's responsibility to have printed samples of fingerprinting tests available on commonly used papers so that clients may have a visual guide to choosing an lpi screen that is appropriate for the specified paper.

Deformation of Halftone Dots

Unfortunately, halftone dot sizes specified by careful photographic exposures or through the use of Photoshop do not necessarily print the designated size on the press. The pressure used to transfer the ink to the substrate, coupled with the blotting action of many substrates, causes dots to become enlarged or deformed. For example, if a halftone dot size of 50% is specified in Photoshop, the printing pressure and the paper's blotting action can cause those dots to enlarge to the size of 70% dots. This phenomenon is known as dot gain. Dot gain is not an error or flaw—it is an attribute of print reproduction. It does, however, make halftones look darker than they should. So dot gain must be taken into consideration when preparing grayscale images for reproduction.

In most printing processes, dot gain affects the midtones more than the highlights or shadows (see Note ii). The larger the circumference of the dot, the more likely it will be affected by dot gain. However, dots larger than 50% start to overlap, so they don't appear to gain very much. Tiny highlight dots are usually not greatly affected by dot gain either. Because of the considerable impact of dot gain on midtones, dot gain is generally measured at the 50% dot. When a press is fingerprinted, a 50% dot's size is measured with a densitometer or other dot measuring device. The dot will usually read between 65–85%, a gain of 15–35%. Fifteen percent is considered very good dot gain, 20% is normal, and

Process (paper)	Typical dot gain
Offset lithography - web (coated)	20%
Offset lithography - web (newsprint)	35%
Offset lithography - sheetfed (coated)	15%
Offset lithography - sheetfed (uncoated)	20%
Flexography (coated)	25%
Flexography (uncoated)	40%

Table 2 Examples of dot gain for various process/substrate combinations (see Note iii)

35% is very bad. Table 2 provides some rules-of-thumb for dot gain. However, you should always use the test data for a particular substrate/process/press combination to determine anticipated dot gain.

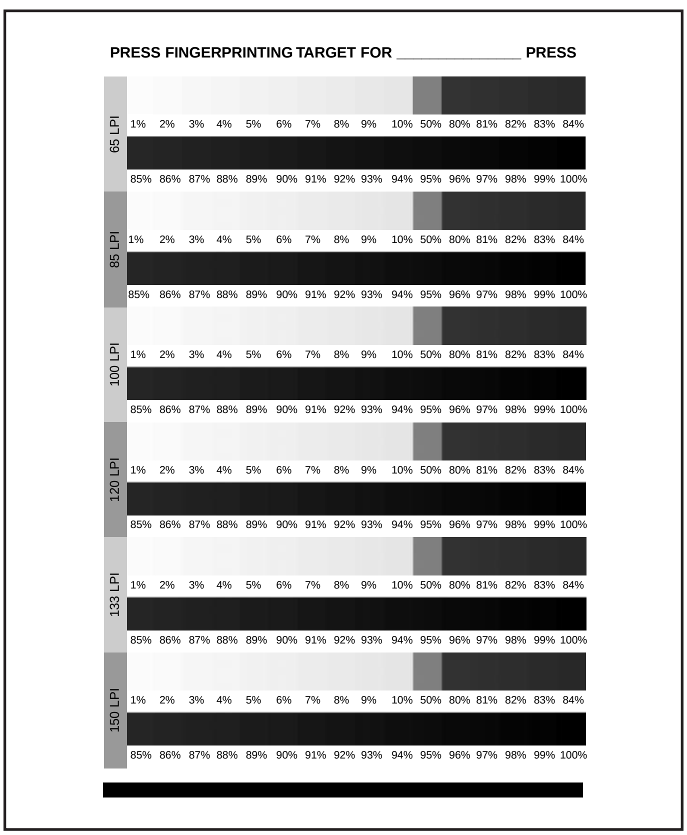

Figure 1

Fingerprinting an Individual Press

Each press in a plant should be carefully tested to determine the smallest printable highlight dot and the largest printable shadow dot that can be effectively reproduced at each commonly used halftone lpi. A test pattern, similar to the one shown in Figure 1, can be devised and used to test each press. The test results are known as the fingerprint of the press.

The test pattern should include individual patches of halftone dots ranging from 1%–10%, 50%, and 80–100%. The pattern should be repeated for each lpi that will be commonly used on a given substrate. For example, if the press is an offset lithographic machine and the paper to be printed is uncoated, at least 120 and 133 lpi should be represented. For an offset lithographic press on coated paper, 120, 133, 150, 175, 200, and 250 line screens should be included.

The fingerprinting target illustrated in Figure 1 was prepared using Photoshop and QuarkXPress. First, a 6×1.5" grayscale document with 266 pixels per inch (ppi) resolution was created in Photoshop. A fixed-size selection was drawn and filled with 1% black using the Color Picker and the Paint Bucket tool. The selection was then copied and pasted. The pasted copy was positioned next to the first selection and filled with 2% black. This process was repeated until all 32 selections in each two-line target were filled as shown on Figure 1. The file was saved in the TIFF format. A new QuarkXPress document was created and six picture boxes were drawn. The same TIFF image was placed into each of the six picture boxes. The Picture Screening dialog box was then used to change the halftone screen lpi of each test pattern to match a screen ruling commonly used on an offset press using uncoated paper. A solid line was added to the bottom of the page to be used to check ink density and balance. (Note: Graphic Arts teachers are welcome to the Photoshop and QuarkXPress files used to create Figure 1. E-Mail the author at JWAITE @UH.EDU to receive the files by return e-mail.) In practice, the lpi of the test patterns should be adjusted to provide a representative range of lpi's for the chosen printing process/substrate combination. For example, if the fingerprinting target will be used for screen-process printing, the range of lpi's should start lower (around 50 lpi) and end lower (around 110 lpi).

After a master file similar to Figure 1 has been created, it must be carefully output on an imagesetter or, in the case of direct-to-plate, on a platesetter. The image on the resultant film or plate must be measured with a densitometer or dot area meter to be certain that the imaged dots are reasonably close to the specified sizes. Film must be measured with a transmission densitometer or dot meter, while plates must be measured with a reflection instrument. (Note: If a dot area meter is not available, standard density readings can be converted to halftone dot size using a conversion table such as Table 7.2 in Adams et al. (1996).) If the actual halftone dot sizes on the film or plate do not reasonably match those specified on the target, the output device must be calibrated and a new film or plate made before continuing the fingerprinting test.

If the target was output to film on an imagesetter, the film must be stripped and plated. When making a plate for a fingerprinting test, it is imperative that proper draw-down is achieved in the vacuum frame to prevent dot gain caused by halation. The vacuum gauge must read at least 22.5" and Newton Rings must be in evidence before the plate is exposed. It is also important that the exposure time be set according to the plate manufacturer's instructions. A transparent platemaker's gray scale or an UGRA scale should be exposed on the plate along with the fingerprinting target to be certain that the plate is properly exposed. After the plate has been processed, it is wise to use a reflection densitometer or dot meter to be sure that little or no dot gain has occurred during platemaking.

Before printing the fingerprinting target on a specified press, it is important to make sure the machine is properly adjusted. For example, on an offset-lithographic press these four press adjustments must be carefully set according to the press manufacturer's instructions: 1) ink-form to plate pressure(s); 2) dampener-form to plate pressure(s); 3) plate to blanket pressure; and 4) blanket to impression pressure. The inking and dampening systems must be set so that an even coverage of an attainable ink density is printed. Other printing processes require different adjustments. In flexography, impression pressure is most critical (Foundation of Flexographic Technical Association, 1991). In screen printing, squeegee shape, pressure, and angle impact dot gain. In addition, off-contact printing helps prevent the substrate from sticking to the screen, a source of dot gain (Adams et al., 1996). The solid black line at the bottom of the form can be used by the press operator to check ink density and coverage.

Once the press has been properly adjusted, the target should then be printed on samples of substrates ordinarily used in the facility. Then, a representative press sheet printed on each type of substrate must be carefully inspected using a 20× or stronger magnifier. The smallest cleanly printed highlight and largest cleanly printed shadow dots in the test pattern representing each lpi should be circled. These dot sizes should be used as targets whenever a grayscale image is being prepared for the specific press, substrate, and lpi represented by the fingerprinting target. For example, on an offset-lithographic press fingerprinting test on uncoated paper, the smallest attainable highlight dot might be 2% using a 65 lpi screen, but 10% using a 133 lpi screen. If a halftone is to be made at 133 lpi using

Figure 2

Figure 3

Figure 4

this particular press and substrate, a 10% dot should be specified for the highlight.

The actual size of the 50% dot patch in each test pattern should be measured with a dot area meter or reflection densitometer and written on the target. For example, the 50% dot patch in the 65 lpi test pattern might measure 70%—the 50% dots have grown in size to appear to be 70% dots. This represents 20% dot gain. To compensate for this dot gain whenever a 65 lpi screen is specified, any area of the grayscale image that measures 70% must be decreased to 50% using Photoshop. When the image is printed on the press, dot gain will cause the 50% dots to become enlarged to measure 70%. In this way, the printed reproduction will more closely match the original gray scale image compared to a printed reproduction that has had no dot gain compensation applied.

Using Adobe Photoshop to Match a Grayscale Image to a Particular Fingerprint

Photoshop has three tools that are very useful in matching a grayscale image to a particular fingerprint. These include the Auto Levels command, the Curves dialog box, and the Duotone Curves dialog box. To illustrate the use of these tools, the procedure used to transform the printed halftone illustrated in Figure 2 into the more pleasing halftone in Figure 4 is given below.

The halftone in Figure 2 began as an RGB color image saved on a Kodak PhotoCD. The original image was opened in Photoshop and converted to a grayscale image using the Mode submenu of the Image menu. In addition, the resolution of the original image was changed to 300 ppi, which is the appropriate resolution for a 150 lpi halftone. Figure 2 is a halftone made directly from that file with no correction applied.

Figure 3 has had the Auto Levels command applied. The Auto Levels command is accessed by choosing Adjust, then Auto Levels, from the Image menu. This command automatically places a 0% halftone dot in the whitest highlight and a 100% halftone dot in the blackest shadow. (Note: If the Auto Levels command does not position a 0% dot in the highlights and a 100% dot in the shadows, the Preferences file is not set at its default settings. To reset the defaults, the Photoshop Preferences file, found in the Preferences folder within the System folder, can be erased. The next time Photoshop is launched, a new Preferences file, containing all the default settings, will automatically be created.) The Auto Levels command automatically expands the copy density range of the grayscale image to its maximum. However, the copy density range must be altered to match the achievable printed density range. The image must also be altered to compensate for dot gain.

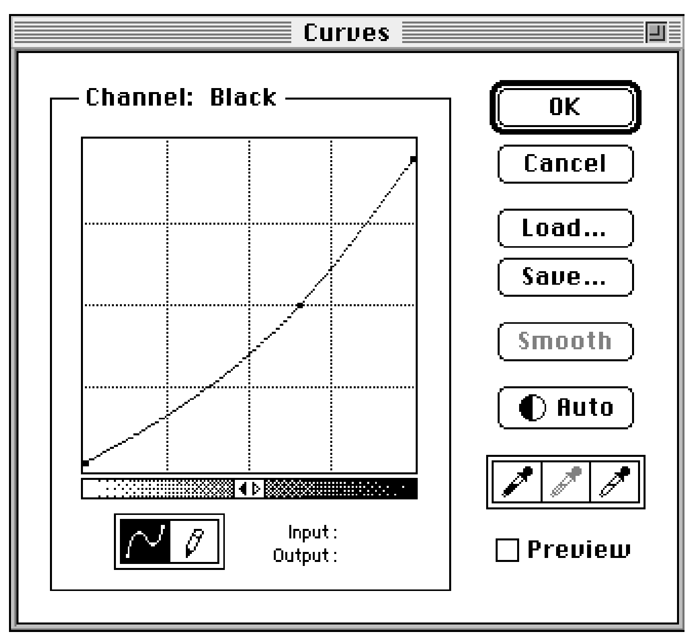

Figure 5

When this paper was written, the author did not have access to the actual fingerprinting data for the press/substrate combination that was ultimately used to print this journal. However, previous journals had been printed on coated paper using sheetfed offset-lithography, so the maximum shadow and minimum highlight dot sizes were derived from Table 1. In particular, the following data were used: 150 lpi screen, 2% minimum highlight dot size, and 95% maximum shadow dot size. Table 2 was used to derive the typical dot gain for sheetfed offset lithography on coated paper—15%. Had actual fingerprinting data been used, the printed reproduction in Figure 4 would look better than it actually does.

Compressing copy density range and accommodating dot gain is best done using the Curves dialog box (accessed by choosing Adjust, then Curves, from the Image menu). Three adjustments must be made to the curve using the Curves dialog box: 1) transforming 0% highlight dots into 2% dots; 2) changing 100% shadow dots into 95% dots; and 3) compensating for the predicted 15% dot gain by making 65% dots into 50% dots. Figure 4 is a halftone that has had those changes applied. Figure 5 illustrates the completed Curves dialog box used to affect the changes. To set the highlight dot size, drag the lowest point of the curve up until the Input field reads 0% and the Output field reads 2%. Similarly, the shadow is set by dragging the highest point of the curve down until the Input field reads 100% and the Output field reads 95%. To compensate for the anticipated 15% dot gain, click anywhere on the middle of the curve and drag until the Input field reads 65% and the Output field reads 50%. Clicking OK closes the dialog box and applies the changes to the image.

If grayscale images will often be prepared for reproduction using the same fingerprinting data, it is best to save the curve so that it can be used again in the future. Clicking the Save button on the Curves dialog box causes another dialog box to be displayed so that the curve can be named and saved in an appropriate place. Later, it is simple to reload the curve by clicking Load to display a dialog box that is used to locate and open the chosen curve. The settings in a loaded curve are automatically applied to the image when the OK button is used to close the Curves dialog box.

The Duotone Curve dialog box is an alternative method for preparing curves. The Duotone Curve dialog box can be used to write curves without actually transforming a grayscale image into a duotone. This dialog box is accessed by displaying a grayscale image on the screen and choosing Duotone from the Mode submenu of the Image menu. The Duotone Options dialog box then appears. After Monotone is chosen from the Type menu and the curve next to Ink 1 is clicked, the Duotone Curve dialog box opens. The size of the smallest printable

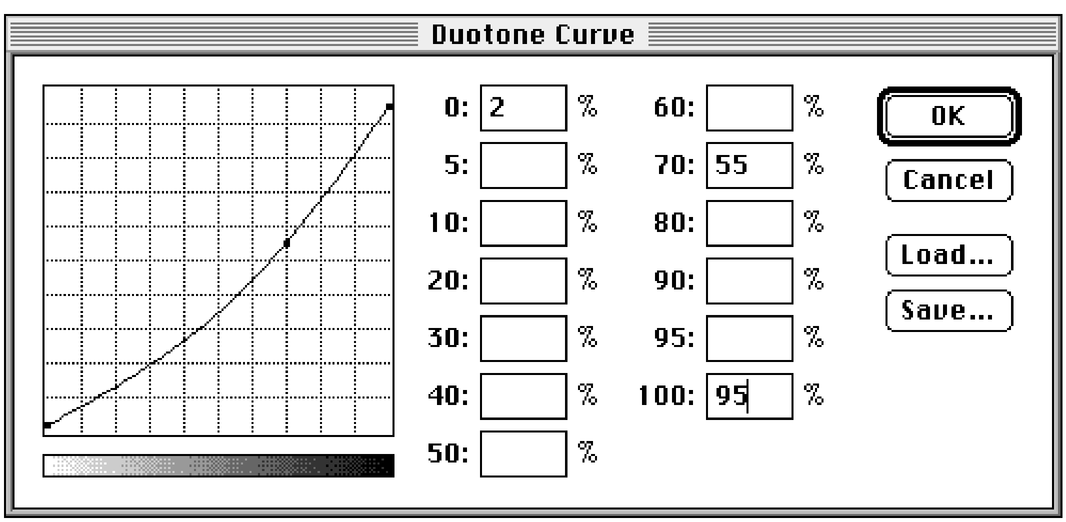

Figure 6

highlight dot (2% in this example) should be entered in the 0% field, type. Similarly, the size of the largest printable shadow dot (95%) should be entered in the 100% field. To compensate for dot gain, an appropriate value must be entered in a midtone dot field. In this example, 15% dot gain is anticipated. Because there is no 65% field in the dialog box, 55% was entered into the 70% field—this value is close enough to transform a 65% dot into a 50% dot. Figure 6 illustrates the completed Duotone Curve dialog box. Once the data has been entered, it should be saved by clicking the Save button. The curve should be appropriately named and saved. Once the curve is saved, the Duotone Curve dialog box is closed by clicking OK. Then, the Duotone Options dialog box closed without transforming the grayscale image into a duotone by clicking the Cancel button.

To apply a curve saved in the Duotone Curve dialog box to a grayscale image, Auto Levels should first be used set the highlight to 0% and the shadow to 100%. Then, the Curves dialog box should be opened and the saved curve loaded. The curve settings will automatically be applied to the grayscale image when OK is clicked to close the Curves dialog box.

Summary

The achievable printed density range of printed halftones is almost always smaller than the copy density range of original continuous tone photographs due to attributes of the ink, the substrate, and the printing press. To produce the best possible reproduction of any continuous tone photograph, the copy density range of the original must be compressed to match the achievable printed density range and a compensation made for dot gain. To determine the achievable printed density range a printing press can produce on a given substrate with a given ink, a series of tests must be run to ascertain the unique fingerprint of the press. The fingerprint of a press impacts the minimum and maximum halftone dots sizes that can be produced as well as evident dot gain. To obtain data necessary to adequately alter original continuous tone images to match the fingerprint of a particular press, a test target, consisting of patches of halftone dots ranging from 1–10%, 50%, and 80–100% dots, should be printed on each commonly used substrate using each halftone lpi that is normally used on a given printing press. Careful examination of the printed targets will provide the minimum and maximum halftone dots sizes that are possible using the particular press/substrate combination. Measuring the actual printed size of the 50% dot area using a dot meter will indicate the percent of dot gain caused by the press.

Once a press has been tested, the minimum and maximum halftone dot sizes and dot gain information can be used in Photoshop to adjust the copy density range of the original to match the achievable printed density range of the printing press/substrate combination. The whitest area of the original is assigned the smallest printable halftone dot size, while the largest printable halftone dot size is assigned to the blackest area of the photograph. The dot gain percent is used to decrease the darkness of the midtone areas. In Photoshop, these adjustments can be made using either the Curves dialog box or the Duotone Curve dialog box.

Notes

i Data in this table derived from Kagy and Adams (1983), Foundation of Flexographic Technical Association (1991), Gravure Association of America (1991), and Posters, Inc.

ii An exception is Flexography, which tends to gain more in the highlights than in the midtones (Foundation of Flexographic Technical Association, 1991).

iii Data in this table derived from Blatner and Fraser (1996), Flexographic Technical Association (1991), Margulis (1995), and Beach (1992).

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