Mathematics, Moiré, And the Artist

Topics: How moiré occurs and how to counteract it.

Column first appeared: June 1997, *Computer Artist* magazine.

Source of this file: Scans of the actual magazine pages.

Author's comment: After more than twenty years this column and the preceding one are still, as far as I know, the best available explanation of what causes moiré and how to angle artwork to avoid it.

This archive, to be released over several years, collects the columns that Dan Margulis wrote under the *Makeready* title between 1993 and 2006. In some cases the columns appear as written; in others the archive contains revised versions that appeared in later books.

Makeready in principle could cover anything related to graphic arts production, but it is best known for its contributions to Photoshop technique, particularly in the field of color correction. In its final years, the column was appearing in six different magazines worldwide (two in the United States).

Dan Margulis teaches small-group master classes in color correction. Information is available at http://www.ledet.com/margulis, which also has a selection of other articles and chapters from Dan's books, and more than a hundred edited threads from Dan's Applied Color Theory e-mail list.

MATHEMATICS, MOIRÉ, AND THE ARTIST

By Dan Margulis

If a hard drive has gotten too noisy, one way to clear up the problem is to haul off and hit it with a sledgehammer. This may strike you as a poor idea, yet many artists do more or less the same thing when they have to reproduce a prescreened original, the topic of both this column and my last one.

If we are unfortunate enough to have a printed piece as original art, I don't mean to suggest that we will be able to match the quality possible if we were working with a chrome. But it doesn't have to be a disaster, either, provided we refrain from the use of sledgehammers.

If we can get it right, there are implications that reach beyond prescreened originals. This is not just a matter of Photoshop technique but of proper scanning as well.

A PATTERN OF DECEPTION

When two or more patterns overlap, unusual things can, but do not always happen, as in the image of the shirt. These sub-patterns are interesting, but they aren't exactly what we want to see in the middle of a piece of art on the printed page.

We who work with print are particularly vulnerable to this disagreeable interference patterning, which is usually called *moiré*, because in reproducing artwork, we generally impose a pattern ourselves, in the form of rows of tiny, evenly spaced dots, otherwise known as a screen ruling. If there is also some kind of pattern in the original art, such as the striped shirt at left, ugly things can happen.

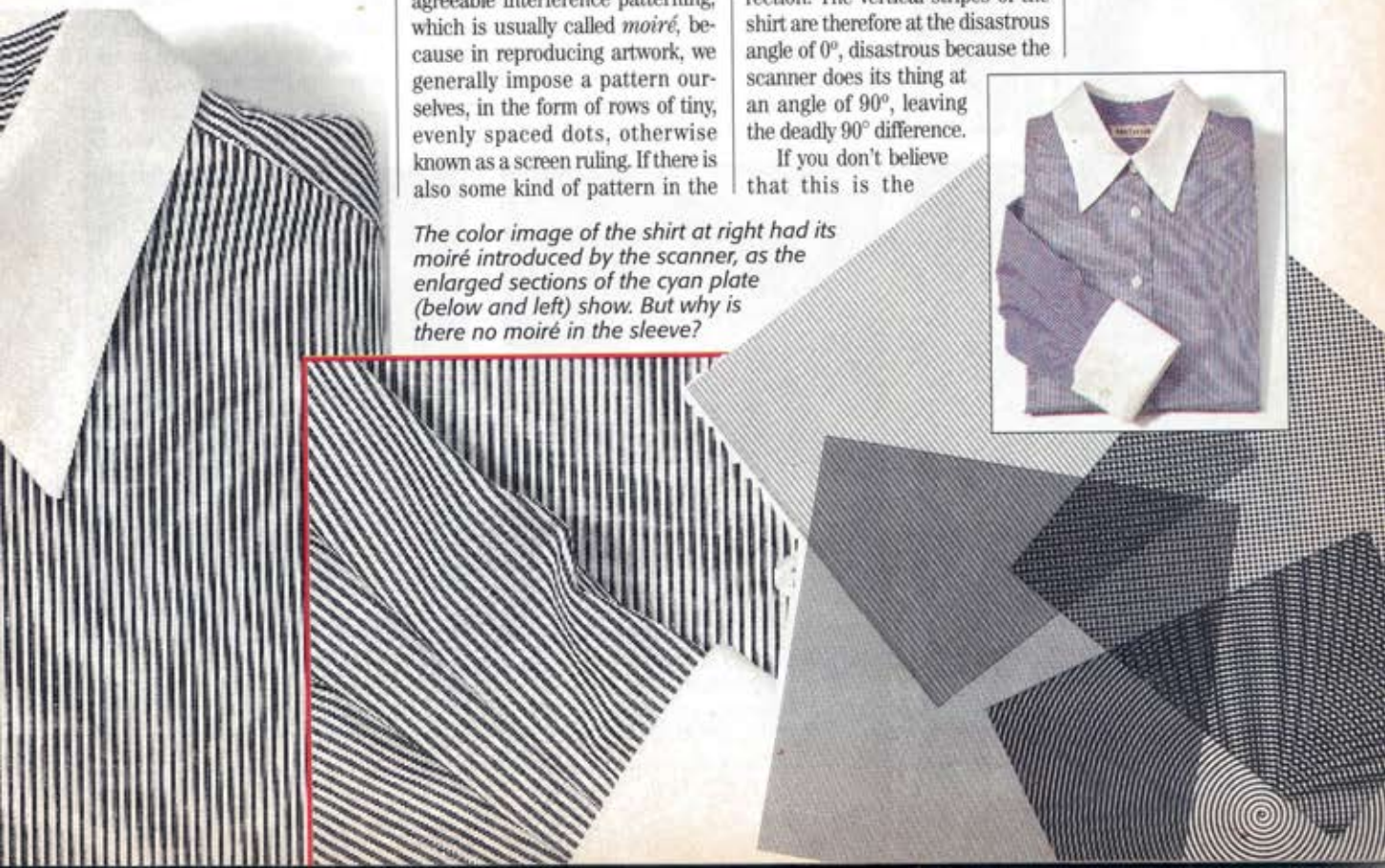
There is, however, a third potential contributor. As the enlarged sections of the cyan plate demonstrate, the moiré is already an integral part of the image, courtesy of the scanner. Even a stochastic screen, which has no pattern, would not help at this point.

The mathematics of moiré are moderately complex. But for our purposes, one grand oversimplification will do. Assuming two patterns of straight lines, having them 30° or 60° apart from one another is best; the same angle, or 90° apart, is worst.

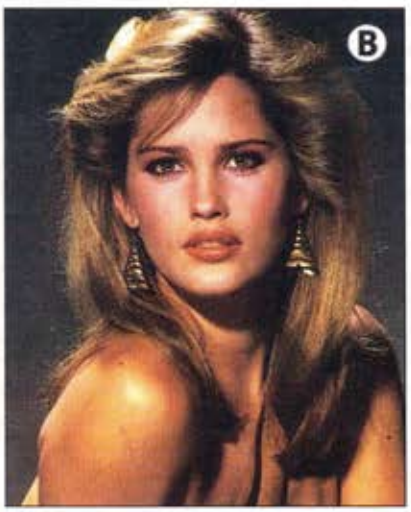
Angling terminology can be ambiguous. For this article, a vertical line is an angle of 0° and other angles measure in the clockwise direction. The vertical stripes of the shirt are therefore at the disastrous angle of 0°, disastrous because the scanner does its thing at an angle of 90°, leaving the deadly 90° difference.

If you don't believe that this is the

Avoiding moiré in prescreened art is not just a matter of Photoshop technique but of proper scanning as well.



The color image of the shirt at right had its moiré introduced by the scanner, as the enlarged sections of the cyan plate (below and left) show. But why is there no moiré in the sleeve?



cause of the problem, have a look at the sleeve. I measure it at 126°, a happy 36° away from the scanning angle, and, by gosh, there isn't a moiré!

The moral is that striped shirts produce moirés only when the scanner operator is asleep. Here, all that had to be done to avoid moiré was to rotate the original by 30° prior to scanning it, intending to reverse the rotation in Photoshop later. By using that angle, the stripes would have been at –60° with respect to the scan and the sleeve at 66°, both nearly optimal.

Last time, we discussed how to descreen black-and-white images. Color images are a little easier—and a little harder. Easier, because moirés will ordinarily not be in all plates and will therefore not be so apparent. Harder, because if one or more plates has a serious moiré, image quality will suffer even if we can't see the moiré in the image as a whole.

And the same, because they are still subject to the 30°-is-best rule; because the idea is to subdue the dots without wiping them out entirely; and because with reasonable care one can get much better results than by using some sort of sledgehammer, such as an automated descreening program.

To illustrate, I'll be working with an image that I also used in a recent edition of our sister publication, *Electronic Publishing*. The original file is shown on this page for reference, but every version with a *B* in the upper right is actually a scan from the printed magazine.

The image of the shirt had a *subject moiré*—there was a pattern in the shirt proper, having nothing to do with printing. In principle, there is no such pattern in the woman's face, but the fact that it has been previously screened introduces *four* patterns, one for each CMYK ink. We need to compensate for that during reprinting, but especially during scanning.

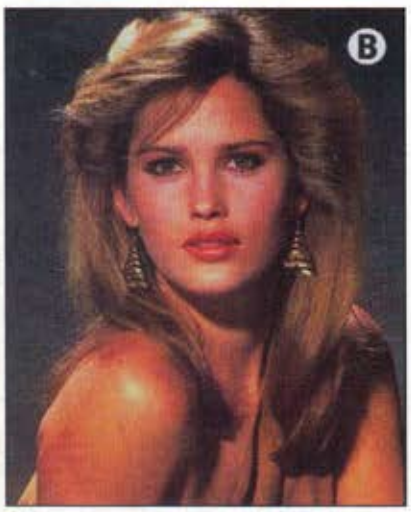
The bottom right version of the original image is a reminder that random screens don't work too well. To avoid such calamities, we need to follow the 30° rule, keeping the screening angles of each ink 30° apart from one another.

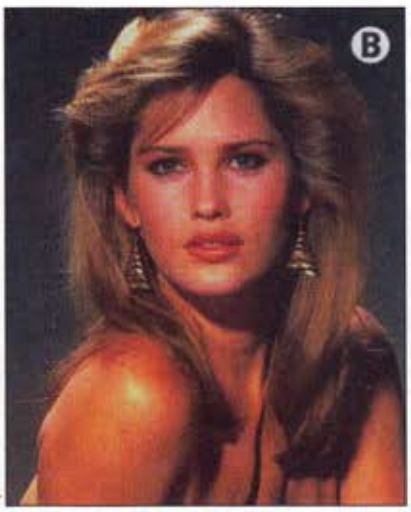
The bad news is, it isn't possible to do this with four inks. Since a screen is a rectangular grid, an angle of 0° is also an angle of 90°. An angle of 30° is also 120°, and so on. If we start with one ink at 0° we can have another at 30° and a third at 60°, but we have just run out of 30° spacings.

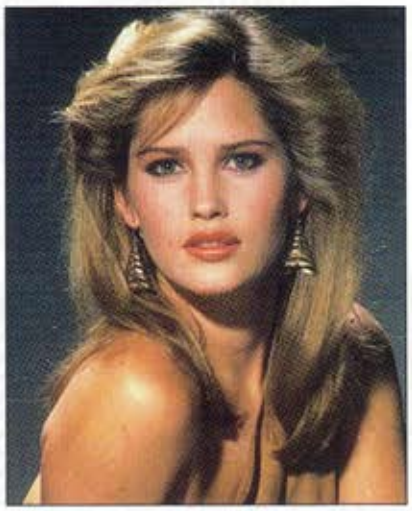
The good news is, we have an ink so weak—namely yellow—that its angle will make little difference. If you don't believe this, have a closer look at the misangled version. Moiré appears everywhere except in the woman's flesh, which is almost entirely defined by magenta and yellow inks. The magenta angle is only relevant if there is something to conflict with it. Yellow doesn't.

Although any 30° combination will work in principle, the normal angles are 15° for the cyan, 45° for the black, 75° for the magenta, and 0° for the yellow. The three strong inks are thus 30° apart from one another.

Given these angles, if we mount a prescreened original in a scanner at the usual angle, zero, *none* of the screens will be 30° away from it. We







Top left, an original digital file. Bottom row, left to right: a scan of the actual printed result done as though it were an ordinary piece of reflective art; a different scan of the printed piece using an automated descreening package; the original file printed with incorrect screen angles (note the color variation from the original, although the files are identical). Middle above, a reproduction of the printed piece using the methods advocated in this column.

therefore should be mounting at an angle, but what that angle should be is open for discussion. For the same reason that only three printing inks can be 30° apart from one another, only *two* can be 30° away from the scanning angle. Which leaves us with some choices to make.

The best scanning angle for prescreened color is usually 45°, which is 30° away from both magenta and cyan. Black and yellow will unfortunately be at relatively bad scanning angles. The importance of these choices is demonstrated in stark form above. This scan was made at a 45° angle, then rotated back to vertical in Photoshop. Above, greatly enlarged, are the resulting RGB channels.

The red and green channels are pretty much defined by the cyan and magenta components, respectively, of the original. Do you see the characteristic 15° angle of the dots in the red, and the 75° angle in the green?

The dot structure, however, is crisp and well-defined. Contrast that to the blue channel, which is based on the yellow component of the original. Moiré has struck! As, indeed, mathematics suggests. The yellow screen angle is zero; rotating the scan as I did places it at 45° relative to the scanner—not good.

This plate will hurt quality, but we'd much rather have a good cyan and magenta than a good yellow. We can recover from that, as I'm about to demonstrate. But if we don't take care in choosing the scan angle, we'll have *every* channel looking like the blue one does above, and then we *will* need a sledgehammer.

SOME RESOLUTIONS

With that mathematical introduction out of the way, let's first resolve not to accept the atrocities shown on the opposite page of either a normal scan or an automated descreen. Both have too many problems to repair. The first has an incipient moiré nearly everywhere; the sledgehammer applied to the second has blown away detail.

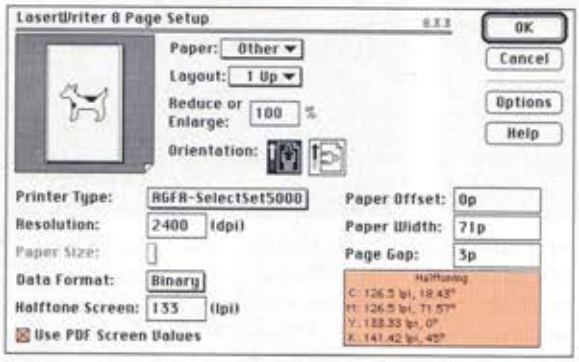
Let us further resolve that this is not to be an all-day affair. With unlimited time, one can reconstruct almost anything.

Finally, let us remember that the dots that make up this image may not be much, but they're all we have as far as detail goes, and we can't afford to damage them. That means no festivals of resampling, blurring, and resharpening, no added noise, and no sledgehammers.

- **Scan at maximum resolution and at the proper angle.** The high resolution softens the image, the proper angle keeps the moiré manageable. For monochrome images, the proper scan angle is 15° or –15°; for color, 45° is usually best, sacrificing a little in the black channel in the interest of better cyan and magenta. In certain darker images, –15°, which sacrifices magenta, or 15°, which sacrifices cyan, may work better.
- **Convert the image to LAB, and blur the A and B channels.** This is a critical step. LAB separates color from contrast, and the A and B define color only. Blurring the A and B eliminates the big color transitions that dots of colored ink cause without damaging detail in the image. Note how much better the blue channel at right is once this blurring is done and the image is reconverted to RGB.

  Choose a Gaussian Blur value that will eliminate the dot pattern in the channel, which you should be able to see easily. The amount of blur will usually be more in the B channel than the A. In the example here, I used a radius of 1.4 in the A and 2.0 in the B.
- **Create a black plate at once.** Set Photoshop's Separation Setup to Light black generation, 85% maximum black, and whatever other values you customarily use. Make a copy of the LAB document as is and convert it to CMYK. You may discard the CMY channels if you like; this version of the document is useful only for its black. The idea is to preserve all the detail possible in the black—the next step will suppress some of the dot pattern in the other plates, but the black is the backbone of the printed image, and we want it to be as close to the original in detail as possible.
- **Reduce the dot pattern in the L channel.** Returning to the original LAB document, open the L channel and descreen it as though it were a black-and-white image. That technique was discussed last time. To recapitulate briefly and somewhat inaccurately: make two copies of the original. Blur one heavily and the other slightly. Apply the heavily blurred version to the original in darken only mode; then apply the slightly blurred version in lighten

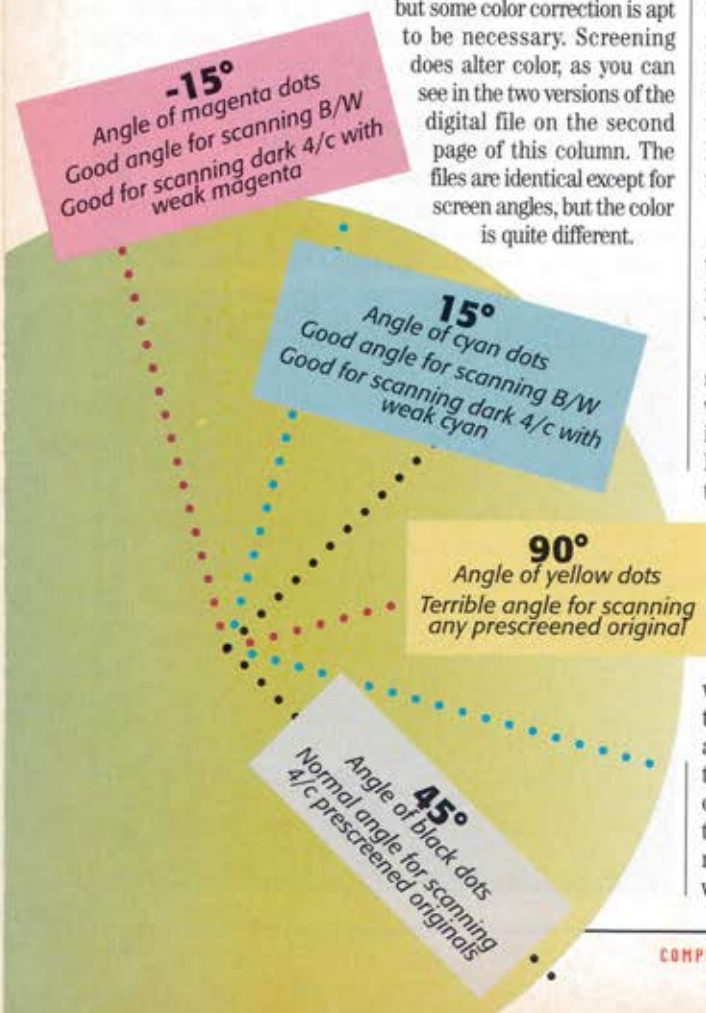
The angle of scanning is critical in dealing with prescreened originals. A 45° angle is optimal in most cases and will give the best capture of the cyan and magenta dots. Above, greatly enlarged, are the red, green, and blue channels of a 45° scan. Note the excellent dot structure in the red and the green. The blue channel, however, has a bad moiré. Below, the blue channel of the same scan after the document has been temporarily converted into LAB and the A and B channels have been blurred.



The graphic below shows the conventional four-color screen angles and offers some suggested scanning angles. Not every imagesetter, however, uses precisely these angles. In any application that is capable of loading PostScript Printer Descriptions (PPDs), we can read what a specific imagesetter will do, as above in the Page Setup dialog box of QuarkXPress.

only mode. This method gives a more uniform tonality without wiping out the dot pattern, which gives the image the small amount of definition it has.

• **Correct color and convert.** This is beyond the scope of this column, but some color correction is apt to be necessary. Screening does alter color, as you can see in the two versions of the digital file on the second page of this column. The files are identical except for screen angles, but the color is quite different.



How you go about this is up to you, but if you are able to set range using the L channel of LAB, that's the best way for a prescreened original. All the rescreened versions on page 10 suffer to some extent from color hot spots, which an L correction wouldn't exaggerate.

• **Replace the black plate.** Since some degradation will have taken place in the last two steps, replace the new black plate with the black plate that was generated earlier.

• **Where is detail unnecessary?** In more places than you might think. In the current picture, we need to hold detail as much as possible in the hair, the eyes, the eyebrows and eyelids, the lips, the earrings, and the garment. But that only amounts to a small fraction of the image's geography. Smoothing out the skin and the background, that's just fine.

Accordingly, if you are comfortable with the use of masks, make a copy of the picture and blur it. Then, merge the two versions together, masking out the portions of the original that have critical detail. If you are uncomfortable with this method, an alternative is to use Photoshop's Blur tool to soften up the face.

In the corrected version on page 10, you can, if you look carefully, detect graininess in the hair, which needs detail. The woman's face, which does not, is smooth.

• **Consider manipulating the screen angles.** In a black-and-white prescreened image, the original screen is almost sure to be 45°. It's virtually automatic, therefore, to change the *output* screen to 15° or 75°, assuring the magic 30° difference. This is done by saving the image in EPS format with screens embedded.

The argument also applies (albeit less strongly) to color work. In finely detailed or color-neutral images, it pays to make, for example, the cyan output angle something other than the angle of the cyan in the original. In a case like the image of the woman, which is not particularly subject to moiré, I wouldn't recommend it.

IF THIS WERE A PERFECT WORLD...

My statement that the correct angles are 15°, 30°, 75°, and 90° isn't quite accurate nowadays. Each imagesetter has different characteristics, and the manufacturers recommend slight differences not just in angle, but in screen frequency as well.

This magazine's imagesetter, for example, runs its cyan at an angle of 18.43°, not 15°, and at a frequency of 126.5 lines per inch, not the 133 we advertise. Our black *is* at the normal 45°, but at a frequency of 141.42 lpi. If you feel the need to swap angles, I suggest you just swap the magenta and cyan, which will be simple and effective. If you are more ambitious, there will be cases where a more aggressive approach will work.

One caution: Photoshop does not give any warning that screens have been embedded in an EPS file, so to save an unsuspecting subsequent user the trouble of murdering you, it would behoove you to name the file so that the subsequent user knows the screens are in there.

It is true that, in a perfect world, we would never have to work with a prescreened original, any more than we would have to take a GIF or other indexed-color image into CMYK for printing, any more than we would have to take a 2MB file up to poster size. But nowadays we get asked to do this kind of thing far more than ever before.

A previously printed piece is not a second-rate, or even a fourth-rate, way to start. It is a grossly defective original, and nobody has any right to expect that we can make it look beautiful. They should, however, be entitled to ask that it not be horrible. If you follow the steps above, it won't be.

Dan Margulis, a Computer Artist *contributing editor, has recently published his latest book,* Makeready, A Prepress Resource *(MIS:Press), which features expanded versions of many of his Makeready columns. The author can be reached by e-mail at 76270.1033@compuserve.com or by fax at 201/763-2835. For information on Dan's three-day, small-group color-correction tutorial in Atlanta, contact Judy Starkweather of PrimeSource at 800/992-4897.*