Tone value increase and polarized vs non-polarized densitometers

John Seymour, 8/18/2003

1 Abstract

It has been noted that the TVI reported by a polarized densitometer and that reported by a non-polarized densitometer do not agree. If TVI is just a measurement of the growth of dots, then all densitometers should report the same number.

The quick answer is that densitometers do not directly measure dot gain, they merely estimate dot gain, based on a simple model of how a halftone reflects light. This model is incomplete, so the answer it gives is not completely correct.

Now for the long explanation...

2 Background

2.1 Physical and optical dot gain

To explain the difference, we need to remember that the density of a halftone patch is actually affected by two different types of phenomena.

The first, of course, is the physical growth of the dots from the plate to the paper. When the plate takes up ink, the ink may lap beyond the edge of the dot on the plate, depending on a number of conditions, such as the amount of water and the surface tension of the ink.

When the ink is transferred to the blanket, and subsequently to the paper, there is some compression at the nip points, which causes the dot to increase in size. Obviously, this depends upon nip pressure, press speed and ink viscosity.

This type of increase in density is referred to as physical dot gain. As can be seen, this sort of tone value increase is dependent upon a number of press conditions that we have some control over, such as the amount of dampening solution, and the packing of plates. It also depends on press conditions that we have little direct control over, such as the temperature of the ink.

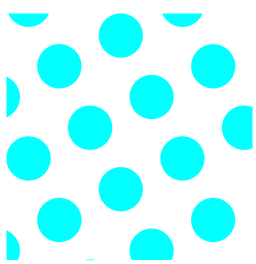
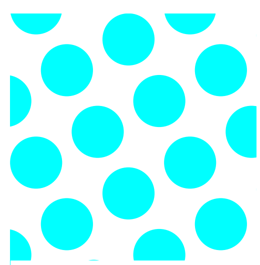


Plate image



Print image

Early on, a device called a planimeter was used to measure dot area. A planimeter is a device that directly measures the area of dots. This could be done, for example, by analyzing pictures of dots under a microscope.

This, of course, is a tedious process. It is fine for research, but it is not of much practical value for a pressman. Thus came the idea for using a densitometer to indirectly measure dot area.

The Murray-Davies equation is the key to estimating dot area by using a densitometer. This equation asks the question: if I know the density of a solid and the density of paper, what dot area would give me a particular density that I read on a halftone?

The Murray-Davies equation is based on a simple assumption about the behavior of light reflecting from a halftone. The assumption is that the light reflecting from a halftone is a simple combination of light reflecting from the solid and light reflecting from the paper. If the dots cover 65% of the surface, then you can predict the reflectance by adding 65% of the reflectance of light from the solid to 35% of the reflectance of light from the paper. Deriving the Murray-Davies equation is simply algebra once you assume this simple model of the physics.

When early researchers first started comparing these two approaches to measuring dot are, it was found that when a densitometer "measured" dot area, it consistently gave a larger number than a planimeter measuring the same spot.

Optical dot gain was offered as an explanation as to why densitometers and planimeters disagreed in the measurement of the size of dots. The idea of dot gain is that a halftone is darker than one would expect because the paper between the dots is not the same color as paper all by itself. The paper in between the dots takes on some of the color of the dots themselves. This happens because some of the light that enters the paper through the halftone dot is scattered within the paper and exits from between the dots.

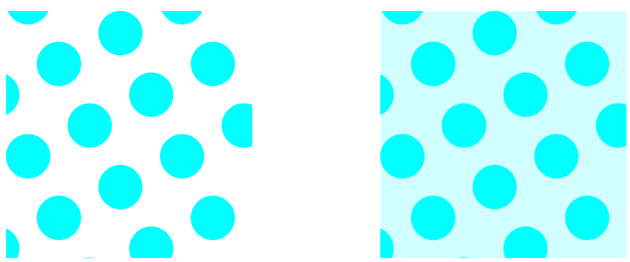


Plate image Print image

This optical dot gain is a second component to tone value increase that goes beyond the size of the dots. A planimeter will not be affected by optical dot gain, but a densitometer will.

Incidentally, the name "dot gain" was originally used to refer to the difference between the dot area on the plate and the dot area reported by the Murray-Davies formula. Later, the phrase "tone value increase" was offered as a more correct name. This name is preferred, since optical dot gain is not really an increase of the dot size, and the same formula was being used to measure gravure, where the size and shape of the dots was less distinct.

The researchers Yule and Nielsen set out to improve on the Murray-Davies equation by incorporating in the optical dot gain. To use the Murray-Davies equation, you need to know the solid ink density as well as the paper density. The Yule-Nielsen equation requires the user to provide a third parameter that characterized the amount of optical dot gain. This parameter has enigmatically become known as the “Yule-Nielsen n-value”.

The name “n-value” is not particularly useful in understanding what the purpose of this parameter is. Another confusing thing about the n-factor is that the number really doesn't have any units associated with it, like percentage points or density. An n-factor of 1 curiously means that there is no optical dot gain, and a value of 3 might be typical.

The precise number that should be used for the true n-value depends upon how much the light scatters in the paper. This in turn depends upon the optical qualities of the paper, but also upon the dot screen. A rather coarse screen such as 100 DPI can be counted on to have smaller optical dot gain than a fine screen such as 175 DPI. Optical dot gain also depends on the shape of the halftone dots and how far the ink penetrates into the paper.

Because the n-value is difficult to estimate and may change from job to job, it has not seen much practical use in the industry. On the other hand, if used properly, it could allow someone to determine a better estimate of the physical dot gain, an estimate that does not include the optical dot gain.

To summarize so far,

1. tone value increase = physical dot gain + optical dot gain.
2. The Murray-Davies equation computes the effective dot size, assuming that there is only physical dot gain.
3. The Yule-Nielsen equation computes the effective dot size, making allowances for optical dot gain.

2.2 Explanation

Now back to the original question. Why does a polarized densitometer provide a different estimate of tone value increase than a non-polarized densitometer?

Obviously, the physical size of the dots does not change when a polarizing filter is put in. The difference must lie in the optical dot gain.

In a 45/0 densitometer without a polarizing filter, the light shines on the sample at 45 degrees, and is measured at 0 degrees. If the surface of the sample were perfectly flat, the specular (surface-reflected) light would leave the sample at 45 degrees and not be measured. To the extent that the surface has some roughness, some amount of the specular light will be reflected to the detector.

By inserting a polarizing filter in the path, there is a marked reduction in the specular light that is captured. This works in the same way that polarized sunglasses reduce glare.

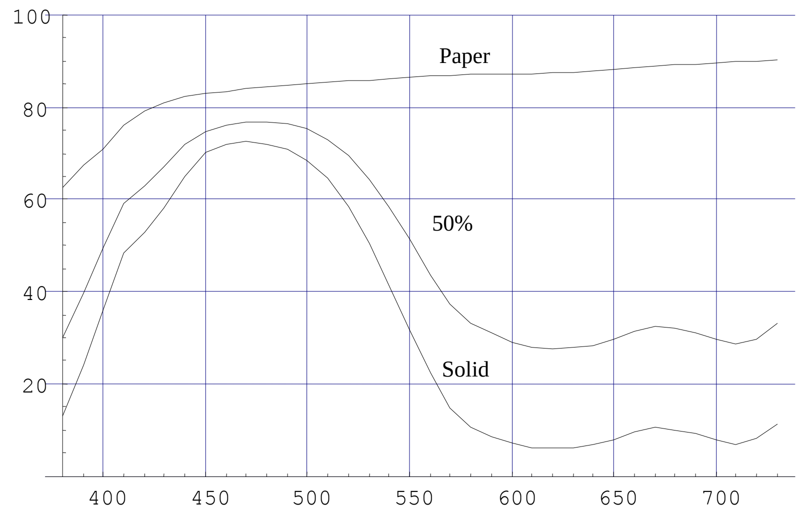
The benefit of polarized densitometry is that a larger portion of the light that is captured is light that contains information about the ink. (Note that the specular light is the same color as the illuminant.) Thus, a polarized densitometer will provide numbers that are more indicative of the actual ink film thickness. In addition, since the smoothness of the surface of the ink has less of an effect on the readings, the change in surface smoothness between dry and wet ink is smaller.

On the other hand, a polarized densitometer is less capable of predicting the appearance of the ink on the paper, or to put it more correctly, a polarized densitometer is less capable of predicting how ink on paper appears to a person who is not wearing polarized sunglasses.

This is a constant dichotomy in measurement of ink on paper. There are two goals in measuring print: to determine appearance and to determine physical properties. These two goals are often at odds with one another.

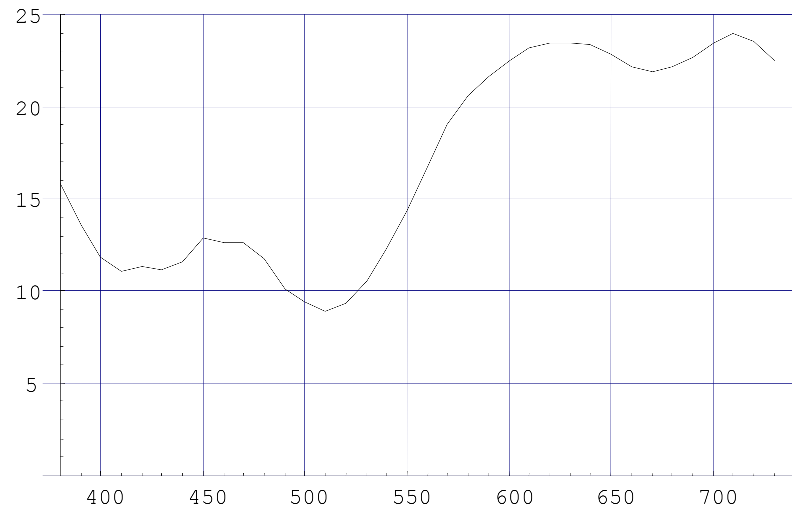
The Murray-Davies equation reports dot area on the assumption that there is only physical dot gain. I assert that in the presence of optical dot gain (which is always the case) the results depend upon the measurement conditions, and can only be compared if the conditions are kept the same.

To illustrate how this can happen, consider the calculation of dot gain for cyan ink. One uses Status T density to compute this. Status T density is based on the reflectance of the sample in the range from 560 nm to 660 nm. There is no particular reason why it needs to be calculated precisely in this range. One would think that the dots would be reported as the same size regardless of what part of the spectrum is used.



The graph at the right shows the reflectance spectrum for paper, a 50% cyan halftone patch and a solid cyan patch. The spectrum was collected with a Gretag spectrophotometer on patches printed within an inch of each other on the same sheet.

What happens if we compute the dot gain (using the Murray-Davies equation) at each wavelength, rather than the normal way?



The graph at the right shows that the computed dot gain depends upon wavelength. The dot gain goes from a minimum of only 8% to a maximum of 24%. Clearly, this is not what we want!

This is another example of how the Murray-Davies formula does not give numbers that can be compared when conditions change. In this case, this shows that the amount of optical dot gain depends upon wavelength. Curiously, the optical dot gain is apparently related to the reflectance of the ink. There appears to be more optical dot gain where the reflectance of the solid is lowest.

3 Summary

The moral of the story is that the Murray-Davies equation for determining dot gain does not consider all factors. In particular, it converts optical dot gain – the scatter of light between the dots – into an effective dot size, which can cause problems. If the conditions of measurement stay the same, then the dot gain numbers can be compared and used as a diagnostic. If the conditions change, however, the dot gain numbers can no longer be directly compared. We have seen that the wavelength we measure at and the presence / absence of a polarizing filter are two conditions that effect the dot gain number.

I expect that changing the gloss of the paper is another thing that would affect the numbers that are returned, but this experiment would be difficult to orquestrate. I suggest that the dot gain be measured on a low gloss sheet, and then again after applying a uniform thin coating of varnish. I predict that there will be considerable change in the dot gain.