CTP - Why densitometers do not work

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Abstract

The advent of CTP has highlighted a problem with quality control, namely that conventional densitometry is not reliable enough for consistent readings of half tone values, making calibration difficult to nearly impossible.

Fortunately there is a solution which has been used in laboratories for several years based on video frame grabbing techniques, more recently using a CCD camera. This technology has now been implemented in a hand held unit known as a digital DotMeter, and a description of some of the problems encountered and the solutions will be explained, together with a comparison with analogue densitometers.

Why densitometers do not work

Densitometers have been with us in the Graphic Arts industry for many years now. It has been the one tool available to us that has the ability, though in practice seldom used, of putting some science into what is still considered by many to be an art form. Its use for the stable production of film output, and calibration thereof cannot be ignored. Neither can its use in the pressroom for

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the control of ink weights and associated factors be understated. However when it comes to the area of checking quality of printing plates from a CTP system, this is one area that the densitometer cannot be applied.

Who says?

3M-Imation in a presentation at these proceedings in 1997. [1]

Another important body of opinion to share this view is that of other plate manufacturers, all of whom rely on planimeter and / or microscopy techniques to obtain accurate results.

Thirdly, densitometer users themselves - in many respects THE most relevant witnesses in the case - have found that these devices are less than helpful in a CTP environment.

And, last and probably least, I am saying so right now!

Why don't they work?

Before the advent of CTP the production of printing plates was a reasonably predictable process with various control mechanisms in place to ensure faithful transfer of known film to plate. The film is of course 'known' thanks to the good ol' densitometer. These transfer techniques of film to plate usually include the reproduction of a grid / wedge to give the correct exposure level. Such systems have been emulated quite successfully [2] on CTP systems. However exposure level alone is not the only requirement when it comes to CTP. Linearisation of the percentage dot on the plate is also a function of the recorder aperture and size [3] and not just exposure level.

The grain profile of the plate will also have an effect on the accuracy of the densitometer readings, as will variations in plate material and emulsion. On plate the actual density of the emulsion is generally non-critical and certainly on thermal plate can only be of interest to the offset lithographic plate manufacturer. In general the density (solid tone) on plate bears no relationship as to its ability to hold or reject ink and transfer to paper. What is critical is the percentage dot areas on the plate that will transfer an image to paper. That is what this business is all about

Another important aspect is the human factor. Operators may have specified an incorrect tint value. Hopefully this would get noticed on film, either by eye or densitometer, before the press was run. This is far more difficult with CTP where the densitometer cannot be relied upon. For example, how can you check a high-light dot in the middle of a plate, away from manual calibration areas.

Reflectance itself brings further problems. If the surface being measured was a perfect mirror, then the reflected density would be infinite, because all of the light would get reflected straight back to the source with none ever reaching the sensor (light detector). If the surface was totally randomly rough then a random proportion of light would get into the sensor.

This phenomenon is, of course, only due to the surface reflectance and has nothing to do with measuring the reflected density, other than make it harder. To over-come this problem a well known modification to the famous Murray-Davies equation - the Yule-Nielsen equation - was developed, originally for the specific application of ink on paper. When applied to plates it can only be effective provided the user knows the 'n' factor for the plate for each type of plate.

Finally there is also a potential problem with electronic stability which will become more and more critical as the density range to be worked with gets smaller.

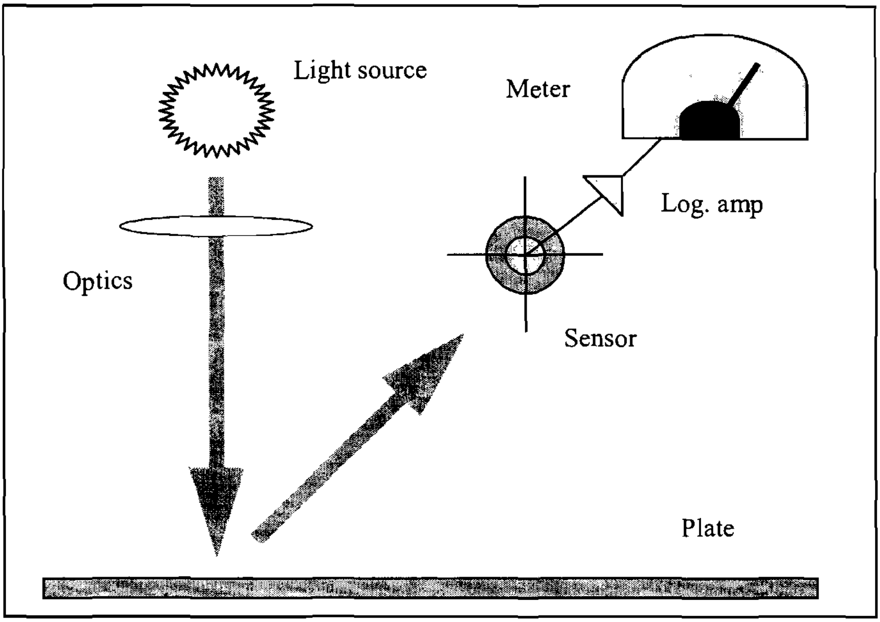
Hence my opening comment that densitometers 'do not work' on plates and therefore cannot be relied upon. To justify this we need to look at the workings of a reflection densitometer.

How densitometers try to work

Fig 1 depicts a typical model which complies with the ISO specification.[4] for such devices. A collimated light source is used to illuminate the sample and detected by a sensor at 45 degrees. This is then converted to density via a log amp and displayed on a meter, perhaps with other compensations applied.

When attempting to use a densitometer to measure percentage dot, it is necessary to know the white and black level of the plate. Here in practice is the first problem. Namely that any variation in the white or black level across the plate will have a direct effect on any reading taken. In practice variations of +/-13% have been seen across the plate background (white area). Again the only way that a densitometer can be used as a DotMeter for plates is by very careful calibration of the black and white levels within very close proximity of the target area. This also *assumes* that you know the 'n' factor for the plate.

The accuracy of the result obtained is the next issue to address. If the 'black' of the plate is say 1.0 D, this means that in reflectance terms 10% of light is reflected, and the 'white' by definition is 100% reflected. A 50% tint area is made up of equal areas of 'black' and 'white' so that in reflectance terms a total of 55% (i.e. half of the white plus half of the light from the black) is reflected.



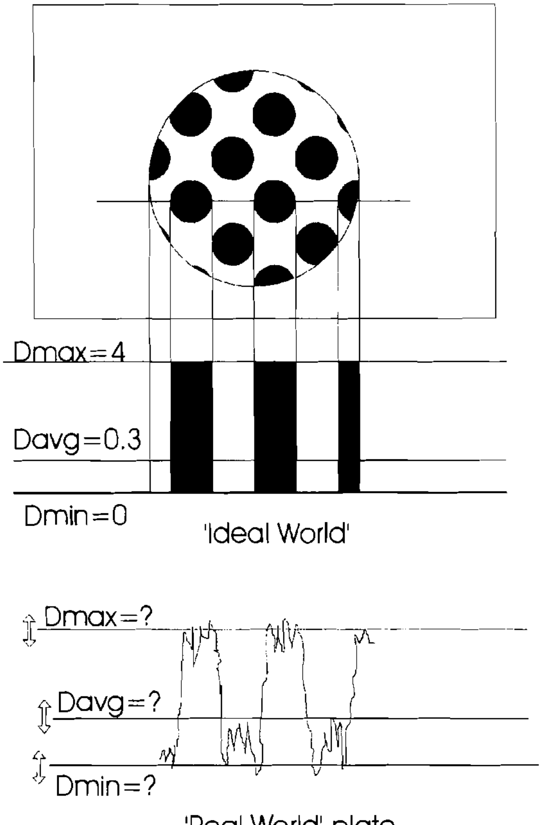
As density = -log (Reflectance) this equates to a density of 0.2596 as compared to the 0.3 one would expect in a perfect world. A chart showing the effect of Dmax is shown in Fig 2 below.

D.max	Reflectance %	Corresponding density for various tint values 1%	10%	49%	50%	90%	99%
3.00	0.10	0.0044	0.0457	0.3094	0.3006	0.9996	1.9590
2.00	1.00	0.0043	0.0453	0.3053	0.2967	0.9626	1.7011
1.50	3.16	0.0042	0.0442	0.2957	0.2875	0.8912	1.3840
1.00	10.00	0.0039	0.0410	0.2668	0.2596	0.7212	0.9626
0.90	12.59	0.0038	0.0397	0.2563	0.2495	0.6710	0.8708
0.80	15.85	0.0037	0.0382	0.2435	0.2371	0.6150	0.7775
0.70	19.95	0.0035	0.0362	0.2279	0.2220	0.5535	0.6829
0.60	25.12	0.0033	0.0338	0.2089	0.2037	0.4867	0.5872
0.50	31.62	0.0030	0.0308	0.1862	0.1817	0.4150	0.4907
0.40	39.81	0.0026	0.0270	0.1592	0.1555	0.3389	0.3935

Though this is of course taken care of by the densitometer manufacturers as far as the user is concerned, the fact is that the smaller the density range to work with the more susceptible the unit is to errors due to electronic drift from noise and temperature.

Where densitometers go wrong

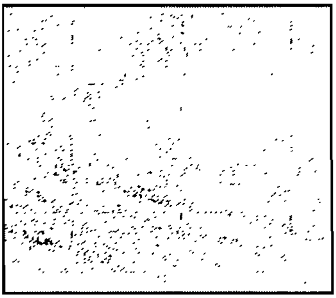
A comparison between the arrangement of dots on a piece of film and the equivalent arrangement on an average printing plate makes it easy to understand why a densitometer has little trouble giving a reading from the former, whereas it encounters enormous problems in interpreting the latter (as the following diagram shows).



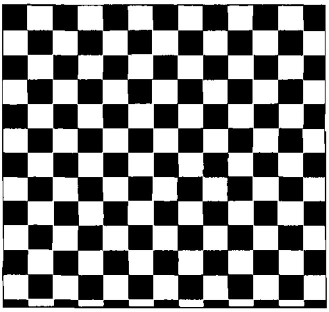
The distribution of dots on the smooth surface of the film is easily calculable and hence represents something very much like an 'Ideal World'.

In the 'Real World' of the printing plate, however, there is no such comfort. The 'noise' from the plate material makes it effectively impossible to obtain trustworthy results with traditional methods and devices designed to operate on film.

Densitometer - image view



DotMeter - image view



Which one is 50% ?

What are the options?

So how can we measure percentage dot area on CTP and conventional plate systems?

There is the age old 'eyeball' method which, by definition, implies a significant element of what we must call 'guesswork'. Following this route, you could expect a level of accuracy that has a potential error margin of +/- 20%. At some time the skilled 'dot etcher' will leave the company, then the delta may become +/- 30%

A good loupe and experience will bring it down to +/- 10%.

You could use a densitometer and hope for the best and you should get to within +/- 5% of the correct reading.

For many years plate manufacturers and other research laboratories around the world have used video techniques involving either planimeter or computed results. The planimeter in this application should really be called a 'cyborg' as it is part computer and part human. A photomicrograph is taken of the dot and is then put on a digitising tablet and traced around by hand. The area of the dot is then calculated by the computer. The application of these techniques leads to a dependable accuracy to within +/- 1%.

The important part of this process is that the human operator decides where to 'threshold' the image, that is define the border between the black and white levels of the plate. Clearly, however, such an instrument is not particularly portable or quick to make readings. For many years now there have also been all-electronic planimeters using a microscope, video camera and computer system [5]. Using off the shelf components has again meant a lack of portability.

Within the last few years advances in electronics have enabled the realisation of a portable system, and Centurfax was the first company to realise this concept in the commercial world when a working device was openly demonstrated at Imprinta 97.

Many of the practical problems of using such a system have previously been highlighted and include:

1. Focus of image
2. Exposure control
3. Thresholding
4. Aperture errors.

These problems have been addressed by the development of a commercially viable DotMeter.

What is a DotMeter?

A DotMeter works via the principle of combining a CCD camera with a microscope. The camera takes a 'snap-shot' of the area being measured and literally counts the black and white pixels in the image. Rather than taking an average of dot density (as with a densitometer), the DotMeter is actually measuring image area and providing an absolute value of dot coverage.

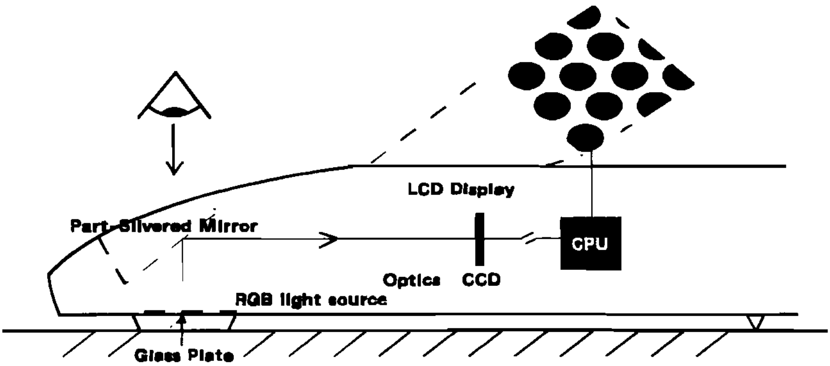
Other key features of the best DotMeters are that it can offer automatic calibration in a single shot (rather than having to be re-calibrated against a known value area before each new reading); it provides additional data on screen ruling and screen angle; and it furnishes users with the ability to read film, plate and paper with one instrument.

It should be stated at this point (April 99) that - to the best of our knowledge - the above mentioned facilities are currently only offered by the CCDot from Centurfax.

How a DotMeter works

The design of a high quality DotMeter includes a glass disc of approximately 25mm diameter which is placed on the sample plate. This design makes is easy to keep the medium flat, thus maintaining good contact with the sample. It is after all a camera and focus is critical. Depth of focus is typically less than 0.2mm for any such system.

A key design criterion of a high quality DotMeter was to ensure that errors in focus would not be introduced into the unit as a result of movement, as in the case of the typical 'stapler', 'clam shell' or pressure sensitive 'anvil' units based on traditional densitometer design. Instead, a high quality DotMeter uses a partially silvered mirror to give a genuine WYSIWYG viewing system with no moving parts which makes it virtually wear and maintenance free for the user.



Exposure control is another very crucial area in setting up any image analysis system. Most video systems have automatic gain control built in. This will tend to reduce the contrast when placed on, say, a 10% tint as it tends to take the average and not the peak density. The other possibility is to set exposure level dependant on the white and black levels in much the same way as a conventional densitometer. This approach used by some suppliers does make the system susceptible to variations in density, just like a conventional densitometer. A high quality DotMeter on the other hand always finds the best contrast between printing and non-printing areas irrespective of the tint value being examined. A complementary coloured light source guarantees optimum contrast and ensures that process colours are measured accurately. It can take a little while to determine the optimum value as the nearer the value is to a limit, the more difficult it gets to distinguish signal from noise.

Providing that the exposure level has been set correctly, and that the image is in focus, then the image may be thresholded at 50% value with very minor errors. The biggest single problem is the level of optical noise from the medium, however using DSP (digital signal processing) techniques this noise can be overcome. Assuming that a high quality DotMeter is used within its working range (typically 85 lpi - 215 lpi) then errors due to the aperture can be kept to within 0.5%.

Where do you need a DotMeter?

The answers to this question are simple and relatively obvious. A DotMeter is vital for linearising any CTP RIP and is the only viable tool for professional Quality Control to within any acceptable level of accuracy.

This is all very well if the object of the exercise is only the pursuit of technical excellence. But is this merely the beauty of the abstract? Is there really any commercial benefit in being sure that you have got it 'nearly right' or is this just a lot of fuss attempting to seek unnecessary levels of near perfection? Surely there is more to it than this.

A recent submission by a major US print corporation offered the results of research and analysis into the actual cost of errors in the printing industry. This high-profile group produced an estimate that the average direct cost incurred is approximately US$650 per error, which makes a device to avoid these problems excellent value for money.

This in itself is significant enough. But, to the best of our knowledge, this figure does not take into account the enormous hidden cost of repeat business lost as a result of the errors in question.

What we have to ask ourselves is: "What is the 'n' (nuisance) factor for these hidden costs?"

I offer you the following equation as an expression of this potential commercial catastrophe.

$$\$(n) = \sum_{\$=0}^{\infty} \left(\frac{x^k}{£!} \left(\frac{d^k f(\$)}{dx^k} \right)_{x=0} \right)$$

where 'n' = 'no profit'

What's the 'n' factor? Well, working it out exactly is of course only marginally relevant, and the equation like the real solution is impossible to solve, but would probably feature a very large number ending in zeros!

Appendix

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[1] Characterisation of Plate Images Part 2, Integrative Sphere Densitometry.
S A Bartels, R S Fisch, D A Nelson, Taga Proceedings 1997
[2] A method for Determining Halftone Dot Area using a Calibrated Visual Reference.
David J Romano, Taga Proceedings 1998
[3] Recorder Spot Size and Its Effect on Image Quality and Halftone Reproduction. David J Romano, Taga Proceedings 1999
[4] Photography-Density Measurements Part 4, Geometric conditions for reflection density ISO reference number, ISO 5-4:1995(E)
[5] The Image Analyser - A True Dot Area Meter? David J Romano, Taga Proceedings 1996