Measurement of Dot Area

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Abstract: In this project, three different methods of image analysis have been compared to determine the physical area of dots on five different substrates, on uncoated, matte coated and gloss coated papers, film and plate. The purpose of this study was to learn the advantages and drawbacks of each method, to write down the procedure of measuring dot area with each device, and to try to determine which one was the best.
The three devices were all based on an optical microscope, an Olympus BH2. The first method used a Jandel planimeter, the second used Adobe Photoshop, and the last one used a new software program at GATF : ImageXpert. Another reason for this work is to evaluate ImageXpert relative to the two other methods.

Introduction

The present report deals with dot area and its measurement. This has been one of the major topics of research of John Lind, who directed this research. The purposes of this report are first to make a synthesis on the topic, then to compare some devices of measurement. Three different devices were actually studied, all based on a microscope, to measure the physical area of dots on several substrates.
In the first part, dot gain (tone value increase) is defined as a mechanical and optical phenomenon and the different ways of measuring dot area are mentioned. In the second part, the devices as well as the methods used to perform the experiments are described and the hypotheses are stated. In the third part, the results are shown, and this leads to a discussion about each device and its limits. Finally a conclusion on dot area measurement opens the debate.

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I - Dealing with Dot Area and Dot Gain

Measuring solid ink density with a densitometer has been the easiest and quicker way to control print quality for a long time. Nevertheless, everybody knows that it is not sufficient to make sure that the color or halftone reproduction is good. Indeed, running a job at the same density levels doesn't guarantee getting the same result. Other parameters like paper and dot gain are at least as important as solid density, maybe even more. Let us focus on dot gain. "Dot gain can cause an overall loss of definition and detail, color changes, problems with contrast. That is why controlling dot gain is essential to maintaining quality in printing." [1]. Figure 1 shows two pictures printed with the same parameters. Only dot gain in magenta was different.

19% dot gain in Magenta

26% dot gain in Magenta

Figure 1 – Pictures printed with the same parameters except dot gain

Efficient and reliable devices are thus to be used to measure accurately dot area on every printed job.

I.1 - Defining Dot Gain

Dot gain is the increase in the area of a dot during the printing process from film or from plate to paper. The increase is usually expressed as a percentage. Two phenomena make up what we call "total dot gain": *mechanical* and *optical* dot gain. This is a complex issue.

Mechanical or physical dot gain occurs several times in the process: first when transferring the image from film (or from file in CTP) to plate. The dot size increases with negative films and decreases with positive films. Then, it occurs in each NIP, that is to say plate/blanket and blanket/substrate. Mechanical dot gain is made up of two components. The one is nondirectionnal and if excessive causes fill-in. The other, called slur, produces a distortion in the direction of the printing and is the result of a "flow" of the rubber surface of the blanket.

Optical gain is a problem of light scattering and absorption. The light is supposed to be reflected completely by the substrate and not at all by the ink. Actually, it doesn't happen exactly in this way. First of all, the ink does not absorb all the light it receives but reflects back a little part of it. Secondly, when the light reaches the non-image area, a part of it is absorbed by the substrate and the rest is scattered. One part of the scattered light is reflected back, the other part is trapped by the dots. (Figure 2)

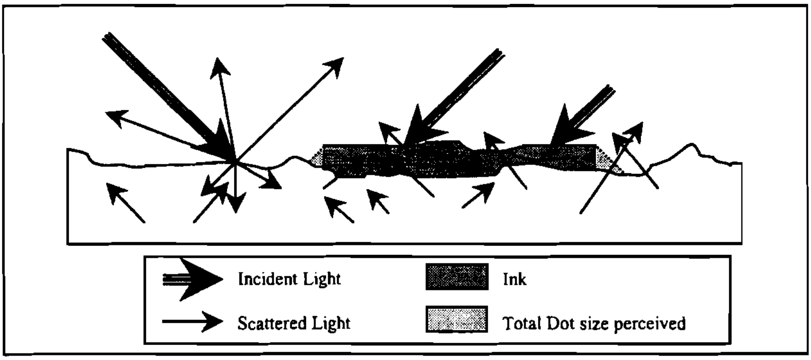


Figure 2 – Light scattering in a printed sheet of paper

Thus, the amount of light reflected by a printed sheet is not exactly the amount of light received in the non-image areas. The amount of light absorbed by the paper and trapped below the halftone dots is nevertheless a lot greater than the amount of light reflected by the dot itself. The result is that we perceive the dots a little darker and bigger than they really are. And so does the densitometer.

I.2 - Measuring dot area

Printers measure dot area with a densitometer using the Murray-Davies equation (1936) [2].

$$a=\frac{1-10^{-(D_t-D_p)}}{1-10^{-(D_s-D_p)}} \qquad \text{(a)}$$

But actually, the densitometer doesn't measure an area. It does measure a density, comparing the incident with the reflected amount of light. That is why the instrument perceives the optical gain. The densitometer "sees" the printed sheet like the human eyes at a reading distance does. Indeed, when one looks at a printed sheet at a reading distance, one doesn't see the dots. If one takes an area corresponding to the separation power of the human eye, the eyes are doing the sum of the light they receive from this area, exactly like the densitometer. That is

why the information given through the Murray-Davies equation is helpful: because it approaches the human eye reaction.
To be closer to the physical area of the dots, Yule and Nielsen (1951) [3], introduced a correcting coefficient n, which depended on the diffusing properties of the substrate as well as on the screen ruling.

$$a=\frac{1-10^{-\frac{Dt-Dp}{n}}}{1-10^{-\frac{Ds-Dp}{n}}} \qquad \text{(b)}$$

This factor, correcting the "error" of the Murray-Davies equation, allows a quite good approximation of the physical area. Nevertheless, this correction is not really convenient insofar as the n factor is different for each kind of paper, and also depends on the screen ruling, so that you have to determine the n factor for each measurement. Milton Pearson (1980) [4] proposed an n value for general conditions at 1.7. This value would give an effective compromise between convenience and accuracy.
With computers, one can measure physical dot area more accurately, with a planimeter, and nowadays with image analysis software. These methods will be fully explained in the next part of this report. With these devices, it is assumed that you can see the physical area of the dot, which is very interesting and complementary with the Yule-Nielsen equation. Nevertheless recent research, performed by Malmqvist (1999) [5], seems to show that there could be a difference between the area seen under the microscope and the area effectively covered by the ink pigment, which could be 15 or 20% smaller.
In this report, the last consideration was not taken into account, and it has been assumed that the real dot area was that seen under the microscope.

II - Devices and measurement methods

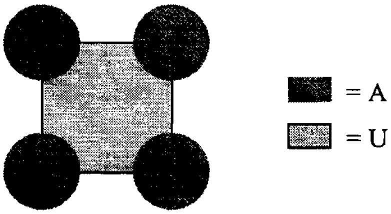
II.1 - The three different devices

The purpose of this study is to compare three different devices available at GATF. They are all based on a microscope. An Olympus BH2 was used for this research. Yet, the rest was different. For each device, a method of measurement was defined that would always be followed for this whole project.

II.1.1 - The Jandel Planimeter

This device involves a video camera, with resolution of 485*376 in a frame of 8.8*6.6 mm, a monitor and a SONY video graphic printer UP-870MD.

A picture is taken and printed at 200X magnification, which gathers at least 4 dots. The center of each dot is determined and drawn with a pen. The unit square area thus determined is considered as the area allowed for one dot and will be called U. Then, using the planimeter, this area is measured, as well as the area of each dot. The dot area is calculated by dividing the average of dot areas measured by U.



$$a = \frac{A/4}{U}$$

Figure 3 - The measurement method with the planimeter

The accuracy of this method depends on both where you set the center of each dot and how you perceive the edge between dot and substrate. There are no rules for that and it depends on each person's sensibility. It depends also on how well one can trace and on how ragged are the edges.
This method has been the reference for a lot of work at GATF for a long time.

II.1.2 - The "Photoshop method"

The material used in this method was a light source, provided by SY Mille Luce, a Kodak DCS 420 digital camera and an Apple G4 computer, with Adobe Photoshop and the driver to acquire pictures from the camera.
A digital picture is taken from the area of measurement and is acquired in Adobe Photoshop, with the grid horizontal as far as possible. If the grid is not horizontal, the image can be easily rotated. Then, a measurement area was defined for each screen ruling which was as accurately as possible from the center of a dot to the center of another one.

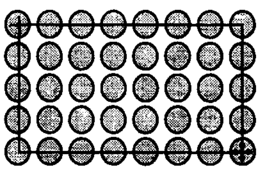


Figure 4 – The measurement area with the "Photoshop" method

The same areas have been used for all the measurements. It has been 7*4=28 dots for coated paper (175 lpi) and 4*2=8 dots on uncoated paper (110 lpi)
Then the image was turned into a grayscale, and the gray level histogram was plotted.

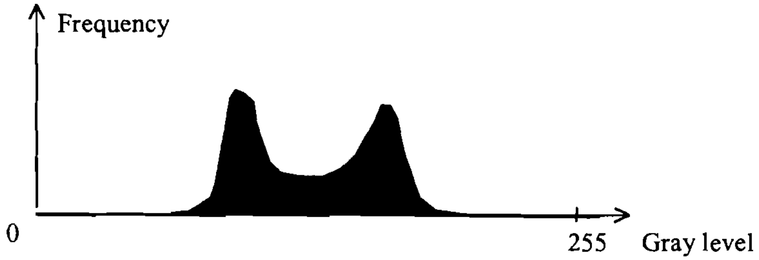


Figure 5 – Histogram of a 50% halftone

The histogram below corresponds to a 50% area. The first peak corresponds to the dots and the second one represents the paper. A threshold has to be found on each histogram to determine which gray level separates the dot from the substrate. Given the threshold, the dot area corresponds to the area under the curve on the left side of the threshold, divided by the area under the whole curve. Photoshop calculates this percentage, so that the threshold has just to be selected along the x-axes. The Photoshop method is fully explained in the last paper of Lind and MacPhee [6].

II.1.3 - The "ImageXpert" Method

ImageXpert is an image analysis software designed by KDY* to analyze printing quality. Usually this software is sold with a motion table and a CCD video camera, which can automatically move on the table. The software and the camera were donated to GATF. This device is very powerful insofar as it is able to quantify the shape, the alignment, the area of the dots, as well as many other things. Only one function of this software has been used for this research: the area function.
The CCD Video camera is attached to the microscope. The live video mode of the software enables movement of the substrate and it is really easy to set and focus on it. When the image on the monitor looks good, a picture can be taken, which will be used for the measurement.
Like in the Photoshop method, an area has to be drawn as the region of interest (ROI). It has been 4*3=12 dots for coated papers and 2*2=4 dots for uncoated

* KDY Inc, 9, Townsend West, Nashua, NH 03063 (www.imagexpert.com)

paper. Then a threshold has to be found on the histogram, and the measurement will be done automatically.
Actually, a sequence has first to be made up to calculate the dot area. Indeed, ImageXpert doesn't give directly the percentage. It only gives the total area of dark and light pixels in *square pixels*. Then, there were two possibilities to calculate dot area:

- $$a = \frac{area\_of\_dark\_pixels}{area\_of\_dark\_pixels + area\_of\_light\_pixels} * 100 \qquad (c)$$

- $a = area\_of\_dark\_pixels$ when the ROI area is calibrated as the unit. (d)

In the first case, one has to draw two ROIs (one to count dark pixels and one to count light ones), to check they are exactly the same and at the same place, and then to define the threshold on each histogram.
In the second case, only one ROI has to be manipulated and the threshold has just to be set once. The only point not to forget is the calibration. ImageXpert gives automatically the area of the ROI in *square pixels*. To define the ROI as the unit square, the square root of the ROI area in pixel has just to be defined as 1.
The second method has been chosen for its simplicity. Obviously, it has been checked that the two methods were giving the same results.

II.2 - Determining the threshold

This is the keyword of image analysis. This notion remains subjective. When looking at the histogram, it is possible to find a point between the two peaks, where the curves stop decreasing and start increasing again: the saddle point. It was assumed that this point is the separation gray level between ink and paper. Nevertheless, sometimes it is wider than one point, and finding the good setting for the threshold can become very subjective. A solution had to be found, which wouldn't be subjective. Several possibilities were studied. The threshold could have been set at:

- the mean of the two peak gray levels, which is always pretty close to the point of the horizontal tangent
- a fixed fraction of the brightest point gray level, but no correlation was found.

Then it was decided to choose the mean of the two peaks, a method explained in the latest paper of John Lind and John Mac Phee (2000)[7].

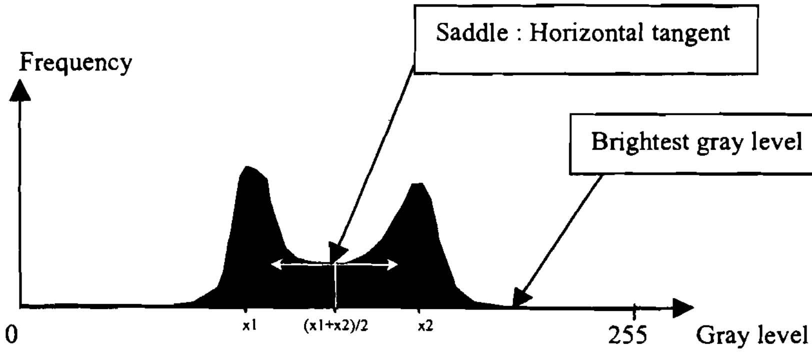


Figure 6 – Saddle point and thresholding

III - Experiments and Results

In order to compare the three devices, some criteria have to be chosen. What is important to know is first of all the accuracy and repeatability of each method. Thus all the possible causes of error were studied.
Then measurements have been performed to compare the results themselves.

III.1 - Experiments to determine the uncertainty of each method

Errors in measurement can have several causes. The first one is the quality of the electronic and optical device that was impossible to quantify but that is involved in each measurement. Thus, this error won't be explicitly discussed in this report.
The second obvious source of error is the amount of light provided to the substrate. This has been one of the most important issues of this project.
Then, we have the appreciation errors, manipulation errors, etc...
Each error was studied for each method, so that it was possible to know what to expect from each device.

III.1.1 - Jandel planimeter error

Besides the error due to the device itself, the influence of the light has been studied, and also how much the operator was involved as well as the repeatability of the measurement with the same operator.

For the repeatability, the same picture was printed ten times and each was measured at different times of the day by the author. The standard deviation obtained was 0.6%.

Then, the same picture was printed three times and three different operators, including the author, measured dot area with the same method. The average standard deviation with several different measurements was 1.42%. We can then estimate the error at about +/– 1.4%.

Finally the influence of light had to be quantified. Pictures have been taken of exactly the same zone, but at different amounts of illumination. The result is that the standard deviation of the measurements was 1.3% between very dark and very light pictures. Therefore, in regular measurements, such extreme cases are rarely involved, and the standard deviation due to the light shouldn't be greater than 1%.
The estimated uncertainty of the measurements with the planimeter is summed up in table 1

Repeatability	0.6%
Influence of the operator	1.4%
Influence of the amount of light	1.0%
Total estimated error	1.8%

Table 1 - The uncertainty with the planimeter method

It was impossible to separate the effect of each error. Then it was decided according to statistical law to calculate the total estimated error by taking the square root of the sum of each square error.

III.1.2 - Photoshop and ImageXpert errors

In these methods, errors can come from the devices themselves, from the determination of the threshold, and from the amount of light.

III.1.2.1 - The threshold

It is actually sometimes difficult to determine where exactly the two peaks are on the histogram. Thus, the deviation in dot area caused by a shift of the threshold on the histogram was studied. From the threshold determined with the method above, it has been varied with +/– 2, as well as +/– 4 gray levels.
It was assumed that the error in determining the threshold could be roughly +/-2 on the x-axis in most of the cases. This leads to an error of +/-1 in dot area with ImageXpert. The same result was found with photoshop, which agrees with the results of John T. Lind and John MacPhee [7].

III.1.2.2 - The influence of both amount and angle of light on the measurements with ImageXpert and Photoshop.

The amount of light provided by the microscope light through the optics was not enough to obtain a good picture for analysis. For this reason, a complementary device using fiber optics was used, made by Mille Luce. It is made up of a central light, which provides two flexible fiber optic arms.
It seemed that the dot area measured under the microscope might depend on the amount of light (as well as on its angle) provided to the substrate to perform the measurements. Thus, the influence of the light source was studied.

The measurements were done on the three different papers. On each substrate, a fixed pattern of a few dots was chosen and only the light parameter was varied.
Since the fiber optic device with flexible arms was not really convenient to control the angle of illumination, the measurements were performed as follow: at fixed angles of illumination, the amount of light was varied. Insofar as it is impossible to measure accurately the angle, three approximate positions of the arms were chosen, which were 45-50 degrees, 60-70 degrees and 80-85 degrees. These angles are evaluated from normal. At such a magnification (100X), the lens must be close to the surface of the substrate. That is why the range of available angles was limited between 45 and 90 degrees.

First of all, it was noticed that at low angles of illumination on an uncoated paper, one could see lighted-up fibers, even under the dots. Some parts of the dots are only coated by a very thin layer of ink (even with no ink at all). In those places, light can enter and also exit fibers. If this part of light is predominant, the fibers can be seen very well, but the light washes out the dot.
Actually, two types of light are reflected by the fibers of paper: one is gloss (from the smooth top or leading edge of fibers above the surface) and the other one is light which enters a fiber, reflects inside and exits all along the fiber wall. As a function of the angle of illumination, these two types of light reach the lens of the microscope at different rates. It seems (figure below) that at low angles from normal, gloss is predominant, while at high angles, it is less important.

Figure 7 – Gloss and angle of illumination

Moreover, on uncoated paper, this phenomenon was so important that there wasn't any peak for the dark areas on the histogram. That is why it was decided to avoid low angles of illumination.
Finally, by looking at the results, it can be seen that there is not that much difference between all the measurements performed.
First of all, with ImageXpert, the biggest deviation in measurements in the same area is 1.8%. This figure is rather encouraging when comparing it with the measurement error due to the threshold, which is 1%. Now if we only consider the angles between 70 and 45 degrees, the biggest deviation becomes 0.5%, and is in the range of measurement errors.
In the Photoshop method, with the digital camera, the exposure can be varied instead of the amount of light. With this method, only a deviation of 0.2%, which seems to agree with what John Lind and John MacPhee obtained in their last research: a non significant variation due to the exposure.
The conclusion of this series of measurement is that the amount of light provided to the substrate is not that important. Up to now, the angle of measurement will be roughly 45 degrees, and the amount of light will be adapted in order to get a histogram with two distinct peaks different from the gray levels 0 and 255. With these statements, we can estimate that the error of the two devices is as shown in table 2:

	Photoshop (percent)	ImageXpert (percent)
Influence of the threshold	1.0	1.0
Influence of the amount of light	0.3	0.5
Total estimated error	1.0	1.1

Table 2 - Estimated error in Photoshop and ImageXpert methods

III.1.3 – Measurements on yellow (influence of the filter)

The purpose of this study is not to compare dot gain between the different colors, but to compare different methods to measure dot area. Thus, it was necessary that all the methods could be applied on each substrate and on each color. It wouldn't be worth it to build up a method, which allows measurements only with Cyan ink. That is why it has been tried on all the primary colors of four color printing: Cyan, Magenta, Yellow and Black (CMYK). For Cyan and Magenta and Black, no problems were encountered, but for Yellow, the contrast between ink and paper was so low, that no peak could be seen on the histogram. The contrast was increased by covering the sheet of paper with a blue filter, which was unfortunately too dark to see anything. Finally, a Cyan sheet of

Matchprint was used as a filter. The contrast was good enough, and the measurements could be performed.
One question remained at that point: does the filter influence the measurement of dot area? To answer this question, the cyan filter was used to measure magenta dots, which can also be measured without filters. The results in table 3, showed that it was not really changing.

Device	Estimated error (percent)
Jandel Planimeter	1.0
Adobe Photoshop	0.5
KDY ImageXpert	0.3

Table 3 – Estimated error with the cyan Matchprint Sheet

This error is actually not really significant when one compares it to the other errors.

III.1.4 - Summary of the errors

Table 4 gathers all the issues discussed previously .

	Jandel Planimeter (percent)	Photoshop (percent)	ImageXpert (percent)
Operator error	0.6	-	-
Operator difference	1.4	-	-
Thresholding	-	1.0	1.0
Amount of light	1.0	0.2	0.5
Blue filter	1.0	0.5	0.3
Total estimated error	2,1	1.1	1.2

Table 4 – Summary of the errors

We can already notice that the planimeter error is greater than the error of the other methods, which behave pretty similar so far.

III.2 - Comparative measurements

At this point, the ways of measuring and the estimated error of each device have been stated.

A series of measurements were performed on three different papers as well as on a plate (Imation Viking) and a negative film. This was done in nominal 25, 50 and 75% areas. The results of these measurements are very interesting insofar as they provide information to compare the results given by the 3 methods.

The results are summarized in table 5.

25 % Area		Jandel	Photoshop	ImageXpert
Film	Average :	24.7	25	24.1
	St dev :	0.6	0.2	0.2
Plate	Average :	29	27.8	28.3
	St dev :	0.8	0.4	0.2
Uncoated Paper	Average :	33.9	31.9	31.4
	St dev :	1.0	0.7	1.2
Matte Coated Paper	Average :	34.1	31.9	31.7
	St dev :	1.3	0.4	0.4
Gloss Coated Paper	Average :	34.2	32.5	32.8
	St dev :	1.1	0.5	0.5

50 % Area		Jandel	Photoshop	ImageXpert
Film	Average :	51.2	51.4	50.0
	St dev :	1.2	0.2	0.5
Plate	Average :	57.4	55.8	55.5
	St dev :	1.0	0.8	0.1
Uncoated Paper	Average :	64.1	63.3	63.4
	St dev :	1.0	0.8	0.7
Matte Coated Paper	Average :	63.5	64.5	64.0
	St dev :	1.8	0.5	0.6
Gloss Coated Paper	Average :	64.1	65.7	65.7
	St dev :	1.7	0.4	0.6

75 % Area		Jandel	Photoshop	ImageXpert
Film	Average :	77.0	76.7	75.8
	St dev :	1.5	0.6	0.5
Plate	Average :	81.8	79.2	79.1
	St dev :	2.6	0.6	0.3
Uncoated Paper	Average :	85.4	81.2	82.4
	St dev :	2.1	1.5	1.3
Matte Coated Paper	Average :	84.1	83.3	82.8
	St dev :	1.7	0.5	0.4
Gloss Coated Paper	Average :	85.8	84.1	84.0
	St dev :	1.8	0.7	0.6

Table 5 – Comparative measuremets

First of all, the standard deviation was examined, which indicates the reliability of the measurement.

Nevertheless, in order to determine which method is the best, a reference would be needed, which is supposed to give the real dot area. For a long time at GATF, Jandel has been the reference. Thus the two other devices have been compared with it.

III.2.1 - The standard deviation of each device:

The average standard deviation of each device is showed in the table below:

	Jandel Planimeter Method	Photoshop Method	ImageXpert Method
Standard Deviation	1.4	0.6	0.5

Table 6 – Average standard deviation of each device

The figures are really significant. The standard deviation with Jandel is almost 3 times greater than that with ImageXpert. This can actually be explained by the number of dots involved in one measurement. In the Jandel method, only a 4-dot area can be measured, while in the other methods, the region of interest, can reach 28 dots. Thus, the least anomaly in one dot, or the least shaking in the measurement has a large impact in the Jandel method while it is attenuated in the other methods.

The same phenomenon can be noticed with the other methods when comparing the standard deviation of coated and uncoated papers, which were printed at different screen rulings, respectively 175 and 110 lpi. In the same area of measurement, only half the dots fit at the 110 ruling. As a consequence, the standard deviation on uncoated papers is greater than on coated papers.
Nevertheless, the standard deviation remains in the range of the measurement error of each device.

III.2.2 - Comparing image analysis with Jandel results

On average, Photoshop and ImageXpert methods provide a smaller result (respectively -1.1 and -1.3%). This difference could come from the method of determining the threshold. In one case, the threshold is determined on the picture itself, while in the other, it is determined systematically on the histogram.
On film, however, the results are very close with all the three devices, which would mean that the threshold may be not the problem.
One result is quite surprising and may be helpful to understand the cause of the difference. On the uncoated paper at 75%, the photoshop method is 4.2% below Jandel and imageXpert is 3% below, which is a lot more than usual. An explanation could come out when looking at the pictures (fig. 8).
It can be seen that on uncoated papers, a dot is far from being a solid. It is actually full of unprinted areas. When measuring with the planimeter, one only traces the perimeter of the dot, thus, one doesn't pay attention to what is inside. On the contrary, an image analysis system examines the whole surface of the dot. Thus, on pictures as shown on figure 8, it seems natural that they return a value significantly lower, especially in the 75% zone in which image area is predominant. This could explain why on average the image analysis systems give lower values.
Nevertheless, a difference in the results between –2 and +2 in most of the case remains absolutely acceptable, especially with the uncertainty of each method.

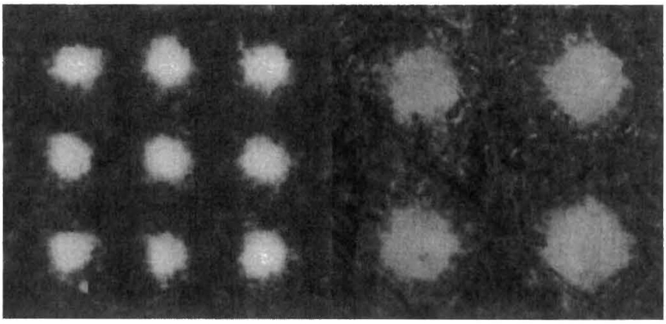


Figure 8 - Unprinted areas (200X magnification) on uncoated paper (on the right) versus a gloss coated paper (on the left)

III.3 - Convenience of each device

Scientific issues have been discussed so far, but let's talk about practical issues now. Among these three devices, it has been determined that Photoshop and ImageXpert each give accurate results most of the time, even if the planimeter is the only reliable device on any substrate. Then, the question was not "which is the best" anymore, but rather, "when is it better to use".
For that purpose, a table has been designed which lists all the practical features of each device.

Device	Strengths	Weaknesses	Estimated accuracy (percent)
Jandel	**Reliable on every substrate**, insofar as you can see what you are measuring.	Not convenient at all, because it is **very long** to perform a measurement.	2,1
Photoshop	The histogram gives the frequency of each gray level, which is really helpful to **determine the peaks.** Changing the exposure is convenient to **adjust the lightness** of the picture	**No live video camera**, so that moving the subject, focusing on it and adapting the light is pretty long. (you have to take a picture every time)	1.1
ImageXpert	Thanks to the live video camera, it is **really easy to adjust any parameter** (light, focus…). Moreover, once the ROI has been settled, the measurements are **very quick**.	No access to the frequency of a gray level so that when the histogram is quite flat, **you can't sometimes determine the peak** but by intuition. **It is too light sensitive,** and thus gives pretty bad pictures with plates.	1.2

Table 7 - Practical issues

Conclusion

Dot gain, with its two components (optical and mechanical gain) has been studied for a long time, and there is no denying that it is a parameter at least as important as solid ink density. Nevertheless, how many printers control dot gain? Only a few. Yet it has to change. And it is the role of researchers to make it easier and more reliable.
However, the printing companies have to realize that to measure only density is just a habit, and a bad habit, they could change with a little bit of training. My opinion is that it will change in this way because a printing company can not afford any longer to make an approximate job. And it is not worth investing huge amounts of money in CTP devices, or in almost completely automatic machines, if at the end of the workflow, the operator doesn't care about tone value increase!

It was not easy at all to compare these three devices, because there is no way to determine exactly the real physical area of a dot. Thus, it was difficult to decide which device gives the best results.
Nevertheless, It has been stated that the planimeter was the only reliable device on all substrates, even if it had the greater uncertainty, mostly due to the "human error" Then, it was found that ImageXpert and photoshop were giving very close results with the same uncertainty. This was expected because of the similarity of the devices. However, if ImageXpert is really the easiest and quickest of those three devices, Photoshop seems to be less light dependent, and thus more reliable on plates. This result needs to be checked by further measurements on a large range of plates.
From experience, measurements on plates are very difficult with both of these two image analysis devices. Indeed, it is very rare to get a good histogram. First of all because of the low contrast between polymer and aluminum, and second of all because of optical artifacts probably due to the roughness of the plate.
It could be the purpose of a future research to find the most reliable device to measure plates. John Lind already compared all the commercial devices available [7]. But, his reference was the planimeter. The point is that one needs to replace the planimeter because printers are going to have to deal with stochastic printing, and stochastic printing can't be measured with the planimeter (it would take one day per measurement). Then, an image analysis software needs to be created specifically for the printing industry, which would be able to measure accurately dot area on any substrate: metals, plastics, papers.
Indeed, nowadays, printing is no longer only on paper, but on every kind of substrate, and with always more diversified plates...

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