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Small Area Colorimetry

Michael R Pointer

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ABSTRACT

This report considers the options available to measure the coloured patches of test charts that can be used to characterise digital cameras to enable them to ‘measure’ colour in a CIE sense. To use a digital camera, as a tristimulus colorimeter requires signal processing to obtain device-independent coordinates, usually CIE tristimulus values, from the output data in the image file, and it is the form and efficiency of this characterisation process that dictates the overall accuracy of the device as a colorimeter. The characterisation of a digital camera using the colorimetric method requires an image of a test chart comprising a suitable number of test patches of known colorimetry. If a traceable path is required, it is necessary to be able to measure the spectral reflectance of each of the test patches using a suitable spectrophotometer that is itself able to provide a traceable path via suitable standard reference standards.

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SMALL-AREA COLORIMETRY

INTRODUCTION

This report considers the options available to measure the coloured patches of test charts that can be used to characterise digital cameras to enable them to ‘measure’ colour in a CIE sense.

To use a digital camera as a tristimulus colorimeter requires signal processing to obtain *device-independent* coordinates, usually CIE tristimulus values X , Y , Z , from the R , G , B output data in the image file, and it is the form and efficiency of this characterisation process that dictates the overall accuracy of the device as a colorimeter¹. The characterisation of a digital camera using the colorimetric method requires an image of a test chart comprising a suitable number of test patches of known colorimetry². If a traceable path is required, it is necessary to be able to measure the spectral reflectance of each of the test patches using a suitable spectrophotometer that is itself able to provide a traceable path via suitable standard reference standards.

TEST CHARTS

GretagMacbeth Charts

There are several methods that can be used to assemble a suitable set of coloured test patches. The easiest to use are the three commercially available test charts manufactured by GretagMacbeth, Table 1.

Table 1. The specifications of the three GretagMacbeth ColorChecker Charts.

	Size	Number of patches	Size of patches	Patch separation
ColorChecker	290 mm x 200 mm	24	40 mm x 40 mm	6 mm
ColorChecker SG	290 mm x 204 mm	140	13.5 mm x 13.5 mm	4 mm
ColorChecker DC	356 mm x 216 mm	237	12 mm x 12 mm	2.5 mm

While these charts are commercially available, they each present some difficulties in use.

- ColorChecker (Fig. 1, upper):
 - o The chart comprises only 18 coloured patches, and some of these are very saturated.
 - o There are only 6 steps in the neutral scale.
 - o The colour patches are mounted behind a thin black card mask to provide a border and care must be taken when placing them onto the port of an integrating sphere-based measuring instrument to ensure that the actual patch is flush with the sphere itself and does not stand-off by the thickness of the mask. This is also likely to be an issue when using some bench 45°:0° instruments.
 - o The patches have a relatively matt finish which means they are prone to surface scuffing. This is alleviated by the relatively low cost of the chart.

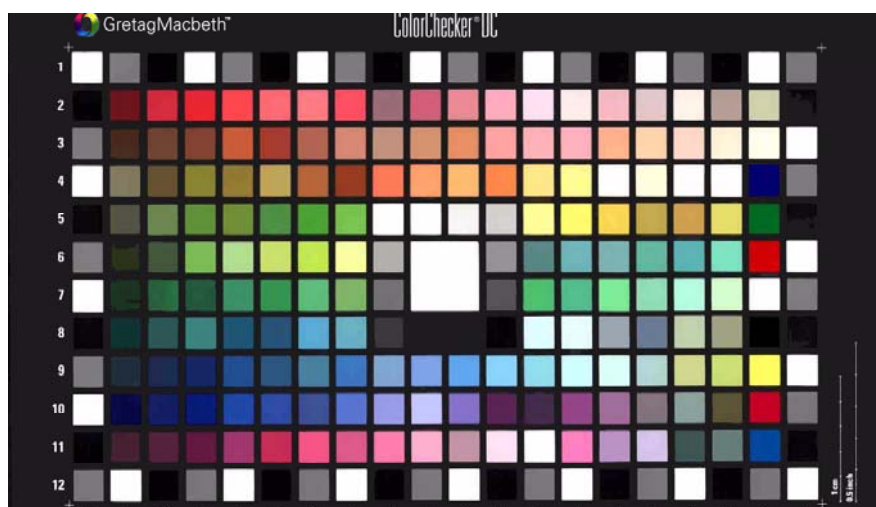
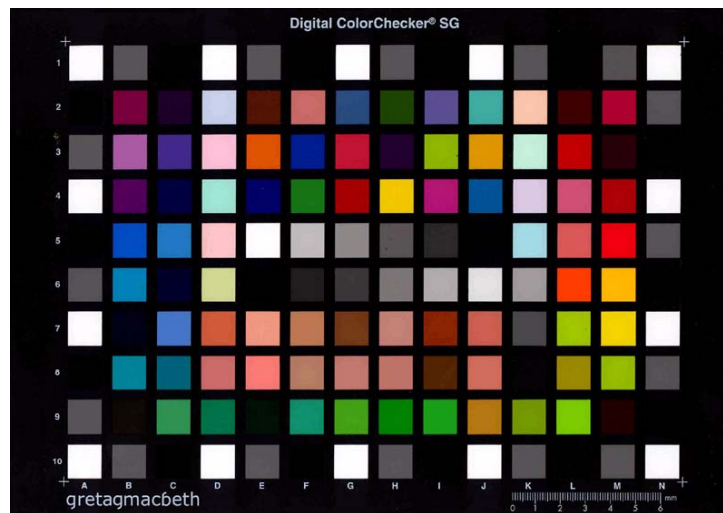


Figure 1. The GretagMacbeth ColorChecker Charts.
Upper, 24 patch 'original' chart; middle, SG chart; lower, DC chart.
The charts are reproduced to approximately the same scale.

- ColorChecker SG (Fig. 1, middle):
 - o The colour patches are small and present measurement difficulties.
 - o This chart probably represents a good compromise in terms of the number of test colours.
 - o The test colours have a higher gloss than those of the above ColorChecker Chart. This can lead to illumination difficulties with a moderately high degree of specular reflection, especially with flash illumination. It is understood however, that a matt version of the chart is to be made available in the future.
 - o The outer ring of patches comprises triplets of three different neutrals intended to monitor uniformity of illumination and exposure. If these are all used in the characterisation process, then they could bias the result towards neutral colours – while not always a bad thing, it may not give the best overall result.
 - o The whole chart is mounted on very thin black card and thus tends to warp. This is especially noticeable when using lighting that emits a lot of heat. This effect could easily be alleviated by mounting the chart onto a suitable sheet of aluminium to provide rigidity.
- ColorChecker DC (Fig. 1, lower):
 - o The colour patches are very small and hence difficult to measure without using a small aperture on an integrating sphere-based spectrophotometer. $0^\circ:45^\circ$ (or $45^\circ:0^\circ$) geometry is easier but again a relatively small aperture is required.
 - o It is probably not necessary to have 237 coloured patches to characterise a digital camera.
 - o The grey scale is close to the central white patch, which is four times the area of the other patches. This means that flare light, reflected from this white patch, can spill over onto the surrounding patches that comprise the grey scale, causing an increase in their apparent lightness.
 - o The chart contains a number of high gloss patches which can cause problems by exhibiting specular highlights – these should be omitted from any characterisation analysis. The other patches are of a gloss level similar to that of the ColorChecker above and hence do not exhibit specular reflection.
 - o As above, the outer ring of patches comprises triplets of three different neutrals intended to monitor uniformity of illumination and exposure. If these are all used in the characterisation process, then they could bias the result towards neutral colours – while not always a bad thing, it may not give the best overall result.
 - o Also as above, the whole chart is mounted on very black thin card and thus tends to warp. This is especially noticeable when using lighting that emits a lot of heat. This effect could easily be alleviated by mounting the chart onto a suitable sheet of aluminium to provide rigidity.
 - o This chart has been available for approximately 5 years and it is likely that it will be superseded by the ColorChecker SG above – or the matt version of it.

Other charts

While the three charts described above are readily available and convenient to use they do not represent the only way in which a selection of coloured patches can be obtained. The following are offered as alternatives:

- The Munsell Students Atlas. This educational tool comprises 10 pages of the Munsell Book of Color. The chips for each page are supplied loose and the student is required to sort them into the scales of Munsell Hue, Value and Chroma and then stick the patches to

the appropriate pages. This represents a very inexpensive method of obtaining a selection of coloured patches (~240) that cover a reasonably large volume of the colour solid. The added advantage is that the patches can be placed by the user into any arrangement to suit a particular application. The disadvantage is that the patches are small (7 mm x 20 mm).

- The separate pages of a colour atlas can be used. Atlases available include the Munsell Book of Color (available as a matt or glossy atlas), the atlas of the Swedish Natural Color System (low sheen samples with some products available with a high gloss finish) and the atlas of the RAL design system (available as a matt or glossy collection of samples). These examples represent options that are rather more expensive but do give a large number of colours.
- There are a number of charts available for use in characterising and evaluating colour reproduction systems and the most used is probably the IT8/7.1 target defined by ANSI, the *American National Standards Institute*, in association with CGATS, the *Committee for Graphic Arts Technologies Standards*³. This 5 in x 7 in chart is extensively used for characterising digital scanners and could be used for a similar operation with digital cameras. Its major disadvantages are that, while it contains 240 colour patches, they are only 6.5 mm by 6.5 mm in size, and that the chart is only produced printed on glossy photographic paper. It is produced by each of the major photographic manufacturers: Kodak*, Fuji and Agfa. Kodak is able to supply generic colorimetric data.

There are obvious advantages in using an industry specific set of samples to make the test chart: these could be readily available and at a low cost. The advantage of using the patches from a colour atlas is that generic colorimetry is available for a number of illuminants. The disadvantage of using any other non-specific, collection of samples is that their CIE colorimetry must be measured.

With the advent of low-cost inkjet printers and suitable software, it is very easy to produce colour charts for specific purposes. An advantage of this method is that the chart can be produced using a small size for each patch, but that larger size patches could be produced for measurement.

COLOUR MEASUREMENT

There are two sets of data required to instigate the camera characterisation procedure: the *R*, *G*, *B* data from an image of each patch in a test chart, and the corresponding CIE *X*, *Y*, *Z* colorimetric data of each of those patches. The way in which the former are obtained is beyond the scope of this report. The latter can be obtained in a number of ways.

Available data – supplied by GretagMacbeth

The GretagMacbeth ColorChecker is supplied with generic colorimetric data for CIE Illuminant SC and the CIE 2° Standard Observer. No spectral data are provided and hence it is not possible to calculate the colorimetry for any other illuminant/observer combination.

The GretagMacbeth ColorChecker SG is supplied with no spectral or colorimetric data.

* Kodak use the product name Professional Q60 target.

The GretagMacbeth ColorChecker DC comes with a CD that includes an ASCII file containing the colorimetric data of each patch. The provenance of the spectral measurement used to calculate these data is not stated but it is known that the colorimetric calculations are based on the use of CIE Illuminant D50 and the CIE 10° Standard Observer. Because the spectral reflectance data are not provided, it is not possible to calculate the colorimetry for any other illuminant/observer combination. In addition, the data are generic in that they represent an average chart rather than the specific chart supplied.

Available data – measured

A set of spectral reflectance data is available for the GretagMacbeth ColorChecker DC, measured using a GretagMacbeth spectrophotometer at the University of Derby. These data were obtained using d:8° geometry, specular included and UV included (i.e. no UV cut-off filter has been inserted in the beam of the illuminating light source in the spectrophotometer). The data are for a wavelength range from 400 nm to 700 nm in steps of 10 nm. From these data, it is possible to calculate CIE colorimetry for any illuminant/observer combination. These data should be assumed available for demonstration purposes only since they were measured using a specific chart which is not now available to NPL.

Another set of data is available for the GretagMacbeth ColorChecker DC, measured at NPL using 45°a:0° geometry and corrected for dark value, scale value and linearity. These data are for 380 nm to 780 nm in steps of 5 nm and were measured using an AvaMouse spectrophotometer. A similar set of data is available for the GretagMacbeth ColorChecker SG chart.

The first of these sets of measured data, the Derby data, does not have a traceable path to the appropriate National Measurement System scale; the second sets, measured using the AvaMouse, do in that the corrections applied to the data are based on measurements made at NPL using reference standards. Thus, by inference, only the latter sets of data can be used to provide a digital camera characterisation that is itself traceable. This traceable path would however, be based on 45°a:0° geometry, and not the perhaps more appropriate d:8° geometry.

POSSIBLE MEASUREMENT METHODS

At the present time, NPL is unable to make traceable measurements of the patches of the two GretagMacbeth ColorChecker Charts with small patches, the DC and SG charts, using d:8° geometry. The Perkin Elmer Lambda 19 instrument used for the reflectance measurement service does not have a small enough aperture to accommodate the patch size of these targets. The instrument that is presently available that could be used for this purpose, a Datacolor Spectraflash 500, is not characterised and therefore has no uncertainty budget. Time could be taken to investigate these measurement uncertainties but there are several factors that negate this option.

The available measurement options are as follows:

Perkin Elmer Lambda 19

The 24 patch GretagMacbeth ColorChecker Chart could be measured using the Perkin Elmer Lambda 19 instrument but the sample holder is constructed in such a manner that the clamp used to hold the sample onto the integrating sphere has to be removed and the sample held in place using alternative means: either by hand or using Blu-tack!

Datacolor Spectraflash 500

This is a bench-top instrument that uses d:8° geometry. Illumination is provided by a xenon source that is flashed into an integrating sphere which is 150 mm in diameter and coated with barium sulphate paint. The diffusion of the illumination is aided by the light entering the sphere via a circular translucent diffusing element 120 mm in diameter constituting approximately 20% of the total sphere surface area. Provision is made to include or exclude the specular component of the light reflected from the sample being measured.

The integrating sphere is 150 mm in diameter and is coated with barium sulphate. The sample port has a diameter of 50 mm and this area can be stopped down with any of a series of interchangeable apertures. These port-reducing apertures have a reasonable knife-edge thus preventing reflections from their edges but they have a metallic shiny finish rather than being painted with barium sulphate. This means that, when the apertures are inserted into the larger aperture they do not ‘complete-the-sphere’ in terms of its reflectance capabilities. It is thought that this failure led to the erroneous data that were obtained in the earlier investigation.

There are a number of problems with the potential use of this instrument:

- This instrument offers three measurement apertures: 25 mm, 10 mm, and 3 mm. In an earlier exercise to investigate the measurement capability of diode-array based instruments, it was shown that there were problems with the measurements made using both the small apertures.
- Another problem, specific to the GretagMacbeth charts, is that the colour patches are mounted on a baseboard and then a mask placed over the top to delineate the patches. This mask has a finite thickness and so, when the patches are placed against the aperture of the integrating sphere, the actual colour patch is mounted a small distance away from the aperture face and, depending on its location in the chart, it might not be parallel to the aperture.
- The sample is held at the aperture of the integrating sphere using a spring-loaded clamp. This must be removed to handle any of the GretagMacbeth charts. There is not a problem in handholding the sample up against the aperture because the instrument measurement time is very short. There would be a problem however, in accurately locating the individual patches over the aperture.
- The replacement to the Datacolor Spectraflash SP500, the Spectraflash SP650, has different sized apertures compared to those of the SP500 instrument: 30 mm, 12 mm, 8 mm and 4.5 mm. It is not known whether these apertures are metallic or painted white.

Thus, while this instrument could be used to measure the patches of all three GretagMacbeth charts, there are good reasons why it might not be appropriate to do so.

It should be noted that the SP500 instrument is no longer the instrument offered by Datacolor: the Spectraflash 650 has superseded it.

GretagMacbeth Color-Eye 2145

This is a bench-top instrument that uses 45°a:0° geometry. Illumination is provided by a pulsed xenon source and a series of mirrors, the last of which forms an annular ring: light illuminates the sample at 45° ± 10°. The sample is held against a 16 mm circular aperture, of which the central 14 mm is illuminated. Light is collected via an optical system from an area of diameter 10 mm centred on the sample.

The use of this instrument is also difficult in that the location and fixing of the chart would require careful alignment and handholding for the same reasons described above for the Datacolor.

X-Rite MA68 II

This portable instrument uses a tungsten-halogen lamp to illuminate a sample area of 12 mm diameter at 45°. Fixed reflectance measurement points are located at aspecular angles of 15°, 25°, 45°, 75° and 110°[#], thus 45° (aspecular) corresponds to measurement normal to the surface of the sample. This geometry is thus designated 45°x:0° indicating that the measurements are made at one azimuthal angle.

This instrument could be used to measure all three GretagMacbeth charts. Alignment is easier in that the instrument is portable and it would be placed on the chart rather than placing the chart on the instrument: it would still require care however, because of the small margin of difference between the size of the measurement aperture and the size of the patches.

AvaMouse

This is a hand-held spectrophotometer and the geometry is similar to that of the GretagMacbeth. Illumination from a pulsed xenon source is conveyed to the sample surface via an annular reflector at 45°. The illuminated aperture is set to 5.5 x 6 mm. and the area of the samples that is measured is 1.5 x 2 mm.

This is probably the easiest instrument that can be used to measure all three charts. Like the X-Rite, it is portable and can be placed on the chart. Its small measurement aperture makes alignment easy and its mode of operation means that measuring a large number of coloured patches can be achieved in a relatively short time. The 237 patches of the GretagMacbeth DC chart could be measured in less than one hour. The data from the instrument require interpolation to produce values from 380 nm to 780 nm with 5 nm intervals (or any other data range and/or spacing); this requires additional time to calculate.

GASP

GASP is a goniospectrophotometer that is able to make measurements using an illumination angle in the range $\pm 75^\circ$, a viewing angle of $\pm 75^\circ$, and with a minimum resolution of 1° . Facilities are provided to move the sample between measurements to enable vertical shift, lateral shift, and rotation. The instrument is uniplanar which means that the illumination beam, the viewing path and their associated scanning directions are all in the same horizontal plane. The detector is a Minolta CS-1000 telespectroradiometer. Because this is an imaging device, essentially a telescope imaging light onto a monochromator/sensor combination, it has a lens with a near focus closer than which it is not possible to focus on to the sample. This distance is 450 mm and this sets the position of the spectroradiometer on its scanning arm. The acceptance angle of the telespectroradiometer is 1° (half angle 0.5°) which has implications on the required size of the illuminating spot of light on the sample. When the sample is illuminated normal to its surface then this spot can be 8 mm in diameter to fill the acceptance angle.

[#] Aspecular angles are those measured with respect to the specular angle. Thus, with illumination at -45° , the aspecular angle is at 45° . Measurement at an angle of 45° , with respect to the aspecular angle, corresponds to a measurement geometry of 45° x:0°.

Thus, test targets with patch sizes greater approximately 8 mm could be measured using GASP. This has the advantage that the x, y stages can be used to move the target such that the illuminating light beam is incident on each patch in turn, all under computer control.

MEASUREMENT UNCERTAINTY

One UK manufacturer of a digital camera based colour measuring instrument is able to characterise the camera to give a median value of CIELAB colour difference of less than 1.0 with all values of colour difference less than 2.0; based on the use of the GretagMacbeth ColorChecker DC chart with 240 colour patches (although not all of the patches are used in the characterisation calculations)⁴. This allows no margin for the uncertainty in the colour measurements of the chart.

If such an uncertainty is included in the process, at a level equal to the average uncertainty associated with the NPL Ceramic Colour Standards, then 3% of the patches would have values of colour difference greater than 2.0 CIELAB units. Increasing this uncertainty by a factor of two leads to 14% of the patches being greater than 2.0 units with 3% of these greater than 3.0 units. Increasing the uncertainty by a factor of three leads to 25% of the patches greater than 2.0 units, with 10% of these greater than 3.0 units and 3% of these greater than 4.0 units. (These figures are based on a model that adds or subtracts random values of uncertainty to the colorimetric measurements of each patch on the chart, within a range set by the defined factor described above.)

It is difficult to set an acceptable level of uncertainty for the measurements of the colorimetric values of the test targets. As can be seen from the above figures, any uncertainty is going to preclude achieving the goal of all colour differences less than 2.0 CIELAB units. The question that perhaps needs to be answered is what is the aim of making the colour measurements. If the aim is to use the digital camera as a tristimulus colorimeter then the answer is that the uncertainties must be as low as possible. If the goal is merely to achieve good colour reproduction on a display screen, then the goal can be relaxed and, as a rule of thumb for pictorial images, all colour differences should be less than 10.0 units with a median value of 3.5 units. This relatively wide tolerance comes about because of a number of contributing factors. Pictorial scenes do not usually contain large areas of colour with no structure, and the shape of the various components of scenes is rarely regular, both these factors serve to make the eye more forgiving in terms of acceptability of colour reproduction. In addition, it is rare for the colour reproduction of every object in a scene to be incorrect and the observer tends to override any discrepancies. Assuming this level of acceptability, Table 2 shows values of median and maximum colour difference to be expected when the average value of the uncertainties of the NPL Ceramic Colour Standards are included in the characterisation process, assuming starting values of 3.5 and 10.0 respectively.

Table 2 shows that the uncertainty can be allowed to increase by a factor of at least three before the median colour difference has increased by one unit. The corresponding increase in the maximum colour difference is also approximately one unit.

Table 2. Values of median and maximum colour difference for different levels of uncertainty

Uncertainty multiplier	Median ΔE^*	Maximum ΔE^*
0	3.0	9.9
1	3.1	10.1
2	3.6	10.3
3	4.1	10.8
4	4.3	11.3
5	4.5	12.5
6	5.0	13.0
7	5.3	13.8
8	6.0	14.8

Table 3 shows the calculated uncertainties in X, Y, Z tristimulus values based on spectral measurements made using of a number of photo-diode array based spectrophotometers. These measurements were the subject of an investigation as part of the previous ORM Programme (2001-04)⁵. The data are based on measurements made using a set of 12 NPL Ceramic Colour Standards, plus a white, a 50% grey and a black gloss ceramic tile. The median and the maximum value are shown in each case. Table 4 shows similar data for a comparable set of matt tiles.

Table 3. Median and maximum uncertainty data for the available instruments calculated using gloss tiles.

Instrument	Aperture	Geometry	Tiles		CIE Colorimetry		
					X	Y	Z
Datacolor	25 mm	d:8° SPEX	Gloss	Median	0.29	0.32	0.31
				Maximum	0.65	0.68	0.73
Datacolor	10 mm	d:8° SPEX	Gloss	Median	0.29	0.32	0.31
				Maximum	0.65	0.68	0.74
Datacolor	3 mm	d:8° SPEX	Gloss	Median	1.87	2.21	1.82
				Maximum	6.78	7.14	7.67
GretagM		45°a:0°	Gloss	Median	0.45	0.41	0.59
				Maximum	1.23	1.10	2.21
X-Rite		45°x:0°	Gloss	Median	0.45	0.49	0.47
				Maximum	1.49	1.50	1.95
AvaMouse		45°a:0°	Gloss	Median	0.97	1.05	1.04
				Maximum	2.08	2.19	2.39

Table 4. Median and maximum uncertainty data for the available instruments calculated using matt tiles.

Instrument	Aperture	Geometry	Tiles		CIE Colorimetry		
					X	Y	Z
Datcolor	25 mm	d:8° SPEX	Matt	Median	0.29	0.31	0.35
				Maximum	0.65	0.69	0.74
Datcolor	10 mm	d:8° SPEX	Matt	Median	1.60	1.79	1.67
				Maximum	4.93	5.07	6.04
Datcolor	3 mm	d:8° SPEX	Matt	Median	2.22	2.49	2.22
				Maximum	5.57	5.78	6.60
GretagM		45°a:0°	Matt	Median	0.70	0.74	0.88
				Maximum	1.56	1.58	2.01
X-Rite		45°x:0°	Matt	Median	1.03	1.10	1.26
				Maximum	2.02	2.05	2.62
AvaMouse		45°a:0°	Matt	Median	1.66	1.83	1.71
				Maximum	3.15	3.40	3.16

The data in the above Tables 3 and 4 suggest that the uncertainty associated with the measurements made using the Datcolor (25 mm aperture) and the GretagMacbeth instruments are such that they would be acceptable for the measurement of the GretagMacbeth Charts – if they could accommodate the small size of the samples. The associated increase in the values of colour difference associated with the characterisation process would be less than one CIELAB unit. The use of the X-Rite instrument is marginal but would probably be acceptable for the measurement of the standard ColorChecker chart.

In all discussions of the impact of measurement uncertainty on the achievable colorimetry of digital camera-based instruments it needs to be remembered that the colour charts used in the characterisation process are not necessarily representative of the samples to be measured in practice. Thus, the agreement achieved between the measured colorimetry of the charts, and that achieved using the instrument will not always translate to the measurement of ‘real’ samples. This is because the camera is a metameric device and two samples seen as identical to the human eye may not be ‘seen’ as identical to the camera. These factors can only add to the likely uncertainty in any measurements made using such a system.

DISCUSSION

From the above analysis it can be seen that the measurement of the coloured patches of the three GretagMacbeth ColorChecker charts is not possible using d:8° geometry. There are several ways in which this situation could be addressed in a cost effective manner:

- Data could be provided using 45°a:0° geometry. While not ideal, for the matt charts this is a not unreasonable alternative to using d:8° geometry. In this case, the easiest instrument to use is the AvaMouse. For the 24 patch chart, the GretagMacbeth Color-Eye 2145 could be used.
- GASP could be used and the diffuse reflectance calculated from a number of goniospectrophotometric measurements. This would provide a solution but GASP is used for other research and it may not always be convenient to use it.
- A Datcolor Spectraflash SP600 could be purchased. Care would have to be taken to ensure that the small apertures are coated in such a manner that they complete the sphere wall when they are fitted into the sphere port.

- A spectrophotometer could be purchased that includes a measuring table that can be driven to a number of specific locations, or a robot arm that can be used to locate the measuring head at any position on a chart. This means that the measuring head can be moved over the chart automatically and measurements made at each required location, all under computer control. Examples of such instruments include the GretagMacbeth Eye-One iO, Fig. 2, the GretagMacbeth Spectrolino, Fig. 3 and a similar instrument available from X-Rite, Fig. 4. The disadvantage of each of these instruments is that they use relatively low-end specification spectrophotometers and thus the uncertainty associated with their measurements is likely to be relatively high. A further disadvantage is that they use 45°a:0° geometry because this geometry is prevalent in the graphic arts industry where they are mainly intended for use.

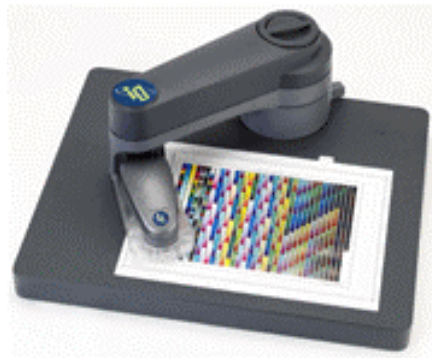


Figure. 2. The GretagMacbeth Eye-One iO instrument.



Figure. 3. The GretagMacbeth Spectrolino with measuring table.



Figure. 4. The X-Rite Pulse QC Ensemble

- Another mitigating factor is that the measurement of these targets may not attract sufficient customers to be viable. Many users of the charts require to know whether a colour reproduction system is working in a satisfactory manner: this judgement is based on a subjective impression. Another use for the targets is in providing profiles for colour management systems, for example input profiles for digital scanners and digital cameras. In this case generic colorimetry is probably adequate. When the targets are to be used for characterising digital cameras to enable them to measure CIE colorimetry, then traceable colorimetric data might be thought to be required. The difficulty is in the cost of acquiring those data. The ColorChecker SG retails at £240 (March 2006) and no user has indicated that they would be prepared to pay more than this for calibrated colorimetric data. For the 24 patch ColorChecker which retails at £70 (March 2006) this is even less likely.
- Measurement services have been unable to fulfill customer requests for measurements because they require the measurement of areas of less than about 25 mm diameter – but this happens rarely.

CONCLUSIONS

If a suitable instrument was already available that provided spectral measurements using $d:8^\circ$ geometry, then it would be worthwhile considering a measurement service using it. It would require the derivation of a suitable uncertainty budget for the spectral data and the colorimetric data calculated from it.

Ideally, the level of uncertainty needs to be such that it adds no more than one unit of CIELAB colour difference to the median value associated with the camera characterisation process. A larger uncertainty may be acceptable but it would depend on the intended use of the colorimetric images produced by the camera system. If the goal of the system is to achieve a median value of colour difference of less than one CIELAB unit, with a maximum value of two units, then the uncertainty needs to be as small as possible because it can only impact on these figures in an adverse manner.

The purchase of a new instrument that provides $d:8^\circ$ geometry however, cannot be justified based on the measurement of coloured charts for digital camera characterisation.

The absence of such an instrument means that data can only be provided using $45^\circ a:0^\circ$ geometry with a moderately large measurement uncertainty.

The purchase of a suitable new instrument with a measuring table or robot arm could automate the process but, with currently available instruments would again provide only $45^\circ a:0^\circ$ geometry.

REFERENCES

1. M R Pointer, Digital Cameras for Colour Measurement, NPL Report COEM/S30, 2000.
2. M R Pointer, G G Attridge, R E Jacobson, Practical Camera Characterisation for Colour Measurement, *Imaging Science Journal*, **49**, 63-80, 2001.
3. CGATS/ANSI IT8.7/2 *Graphic Technology - Color Transmission Target for Input Scanner Calibration*, 1993.
4. M J Shaw, The Measurement of Surface Colour using DigiEye, DQL-OR (RES) 002, 2004.
5. A R Hanson, M R Pointer, P J Clarke, The Uncertainty of Surface Colour Measurements Made with Commercially Available Diode-Array Instrumentation and Recommended Calibration Protocols, NPL Report DQL-OR 005, 2004.

WEBSITES

GretagMacbeth ColorChecker Charts

www.gretagmacbeth.com/index/products/products_color-standards.htm

Munsell Book of Color

www.gretagmacbeth.com/index/products/products_color-standards.htm

Natural Color System

www.ncscolor.com

RAL System

www.dtpstudio.de/raldigital30/english/ral-designsystem_e.htm

Kodak

www.kodak.com/global/en/professional/products/films/catalog/kodakProfessionalQ60Targets.jhtml

Datacolor

www.datacolor.com

GretagMacbeth

www.gretagmacbeth.com

X-Rite

www.xrite.com

AvaMouse

www.avantes.com

DigiEye

www.verivide.com/digieye/home.html

