Q-Enhancer

from Colour-Science AG in Switzerland

The Application of Image Enhancement and Colour Management in Digital Photo-Printing Workflows

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Abstract

Different printer and image enhancement technologies as well as missing colour management support of modern printers make it difficult for the photo labs to print digital images on different printers in a consistent quality.

It is surprising to see how differently a same test image is reproduced on different digital printers, even if their image enhancement is switched off.

We will show the importance of colour management in the digital workflow. ICC printer profiling enables printers to produce standardized output quality. We will also see samples of what happens when we try to print digital camera images with colours which are out of the printer gamut.

Then we learn what the latest developments in image enhancement technology are. We cover standard global image corrections as well as local corrections of density, contrast, colour and sharpness. We will for example see how "Memory Colours" like skin, sky and vegetation are detected and locally enhanced and how density can be locally corrected. We also see what can be done with local sharpening algorithms.

Finally we show a real world example of how these technologies can be implemented in a digital photo lab workflow and how the quality of the production can be monitored.

Introduction

Problems on the way to a perfect print quality

The goal for a photo lab must be to produce the best possible prints from digital camera files and from negative film.

Technically the latest digital photo printers are all excellent printers which means that they print with high resolution (300dpi and more) and consistent colour quality. When printing on silver halide photographic paper then also the colour spaces of the different printers are very similar.

With this in mind the average amateur would think that it should theoretically be possible to print the same image files in a similar good quality in different wholesale labs.

Unfortunately consumer tests of photo labs show that digital printing is not as simple as it seems to be. There are big quality differences between the labs, and there are even differences in the same lab when printing on different paper formats.

There are two main problems on the way to a perfect print quality:

1. The general print characteristic problem

Different digital printers print same images with big differences in density and contrast. Also important colours like skintones, vegetation or sky are printed quite differently. The main problem is that the general balance of the printers is still subject to the individual taste of the engineers who designed the printer. This should not be the case because the way a printer should reproduce a digital image is quite well standardized by the International Colour Consortium.

Printer 1   Printer 2

Figure 1. The same Colour-Science reference printed on two different printers with enhancement switched off.

The proposed solution for this first problem is colour management.

Every printer needs to be ICC profiled. This makes sure that the print quality of all the different printers match one (industry) standard. The fact that the printers are carefully profiled opens you the doors to the professional market.

2. The image enhancement problem

Most printer manufacturers use their own proprietary image enhancement system. Each of these systems will enhance images differently so that the same photo lab using different printers will not be able to produce similar results on different types of equipment.

The proposed solution for this second problem is a centralized printer independent image enhancement.

This allows the lab to use the same type of image enhancement for all the printers. The individual enhancement of the digital printers can be switched off.

Example of a print workflow integrating central colour management and image enhancement for all printers

The following graph shows a workflow configuration which we installed in a Swiss photo lab.
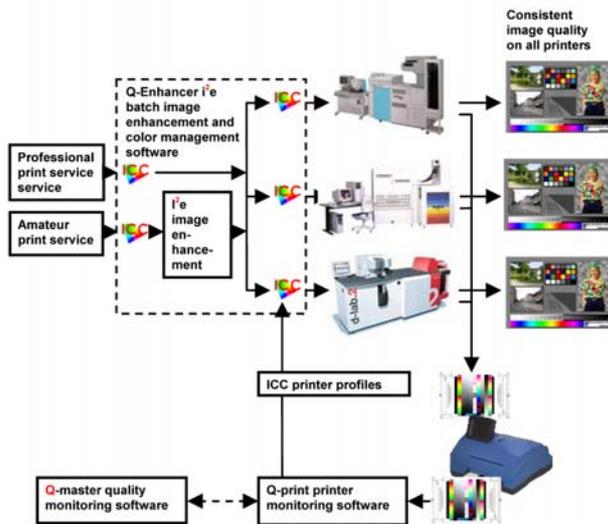

Figure 2. Test workflow in a photo lab.

The above print workflow shows all elements of a standardized and monitored print workflow.

The most important points are:

1. All printers are ICC profiled. This allows us to print same images with exactly the same brightness, contrast and colour rendering independent of the printer or paper type.
2. The lab uses the same image enhancement system for all printers. The different proprietary image enhancement systems of the printers are shut off.
3. The system needs two inputs. One for professional users who want to print on profiled printers and one for amateurs who also want to have their images enhanced.

Practical colour management in photo print workflows

Colour management in printer workflows seems to be quite a straight forward technique. Software to generate printer profiles and software to convert digital images from the image colour space in the printer colour space are available from different companies. These software tools are used for years with success in the graphic arts industry.

In the colour management books the basic setup of a colour managed printer workflow is described like this:
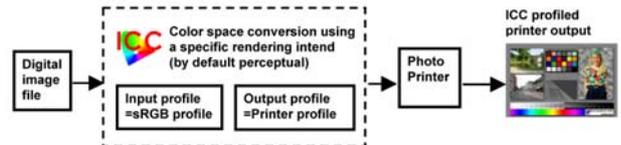

Figure 3. Digital printing of digital camera images on a ICC profiled printer

Generally images of digital cameras having no camera input profile attached are considered to be sRGB images, which means that their colour space is optimised for monitor visualisation.

So the logic way would be to use the sRGB ICC profile as the input profile and a generated printer profile as the output profile. The images are now converted between these two colour spaces and then printed.

The results show us two things. From a density view profiling works well. General density (gamma) and the contrast in the shadows and higlights are now well balanced.

From a colour point of view the result is disapointing and can not be used for a high quality production. Skin tones look reddish and saturated colours, for example in the case of certain flowers, show strange colour effects.

A good example is the sunflower-problem. This is an image of a sunflower photographed in counter light with a normal digital camera. On the screen the leaves show a bright yellow. Printed on a modern laser photo printer parts of the yellow leaves turn greenish, and all details are lost.

Original image   "Colour managed" image

Figure 4. Colour changes in colors which are outside the printer gamut.

The problem is that on the monitor we can see colours which are not printable on a photo printer. These are mostly very bright and saturated colours we find in the vegetation (grass and flowers), in the sky or with clothes. These colours look well on the screen but bad on the print.

Below you see that the sRGB colour space (which is a standardized monitor colour space) is quite larger then the colour space of an average photo printer.
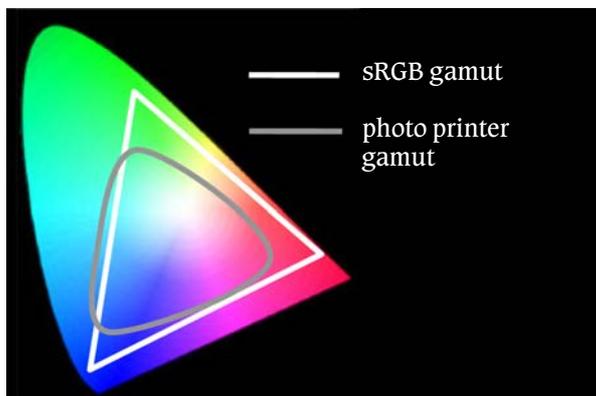

Figure 5. Comparing sRGB and RGB printer gamut.

Now using the sRGB ICC profile as the input profile in our print workflow means that we try to simulate the monitor representation of an image on a printer. Monitor colors which are not printable on the printer are automatically replaced by the nearest color. The way this is done is defined with the rendering intent. For photo printing we should always use the "perceptual" rendering intend, which tries preserving the colours to which the human eye is sensitive when transforming from one colour space to another.

Unfortunately it seems that this does not work well if the input colour space is larger then the printer colour space. In our sunflower problem the bright yellow is replaced with a greenish color which is quite a different unacceptable colour for the observer. In addition to these unwanted changes of the hue angle we see that saturated colours (reds, magentas ..) are mostly printed totally saturated which means that any details are lost. On the edges of the printer gamut a more gradual reduction of colour saturation without change of hue would be much better. But all CMM's (Adobe, Logo, Microsoft ...) seem to have the same difficulties with the replacement of these out of gamut colours.

So it is necessary for colour managed photographic printing to use an input profile which is more adapted to the average printer gamut.

One of the biggest problems for us was now to design such a generic RGB input profile which works well for modern RGB photo printers. Without such a standardized input profile the whole colour management makes no sense.

We have developed a generic profile which works well for most modern photo printers. The most important point was to optimize the colour rendition of skin, sky and vegetation tones.

Using this generic Colour-Science_RGB_ input profile it is now really a straight forward operation to profile a print workflow.

Automated profiling and quality monitoring of photo printers using the Colour-Science Q-Print software

The generation of the printer profile is a procedure which is quite well defined. ICC profiling software packages do not let the user make much choices. Normally we have to print a chart full of color patches. Then we measure this chart using a photospectrometer. With the measured Lab values of the colour patches the software will build the ICC profile.

This is simple and standardized but unfortunately it is quite a manual procedure which is not really usable in a production environment. The chance of making errors is high and every error results in a bad profile. For high volume photo labs it is of an extreme importance that a new printer profile will only replace the old one when every possibility of an error is excluded.

Therefore we developed the Colour-Science Q-print software. With this software ICC profiling becomes so simple that every operator can produce a new profile within 5 minutes.

Step 1. The operator has to print two 4×6" charts with the profiling colour pattern.

Step 2. The two prints are scanned with a fully automatic colour spectrometer.

Step 3. The new printer profile is now generated automatically.

Before the new profile is installed on the printer, Q-print will check the validity of the profile. The profile will be compared to previous profiles. Deviations

(ΔE/max/min) are calculated. If these values remain within intervention limits then the profile is considered valid and installed. It is also possible to visualise a soft proof of the new profile. With this measures it is virtually impossible to install a bad profile and thus produce waste. Most of the time only a simple daily check of the printer is done. For this a simplified pattern on one 4×6" print is measured. With this print we can check colour and density deviations and light distribution. As long as this test is within the limits there is no need to create a new ICC profile of the printer.

Now as we have profiled the printer production lines we can approach image enhancement. Depending on the type of work we will enhance images before we print them in our profiled workflow.

Amateurs want simply the best possible print results. This means that we have to enhance amateur images before printing. Professional photographers however may only want to print on a profiled output device. They do their own image enhancement using Photoshop or similar software.

What they want of the lab is a consistent standardised quality and perhaps the possibility to simulate the labs print result within Photoshop using the soft proofing capabilities.

Image enhancement using the Colour-Science i²e image enhancement library

Colour-Science has with the i²e image enhancement library everything needed to implement image enhancement in print workflows or in the printers.

Behind modern image enhancement is a philosophy which is very different from colour management.

With colour management technology we try to reproduce colours as accurate as possible. Image enhancement now tries to enhance an image as good as possible. If possible the image on the print even looks better then reality. With modern image enhancement technology a greyish cloudy winter day may look on the print much nicer. The snow will sudenly become white instead of gray.

Modern image enhancement technology differenciates two main image enhancement types:
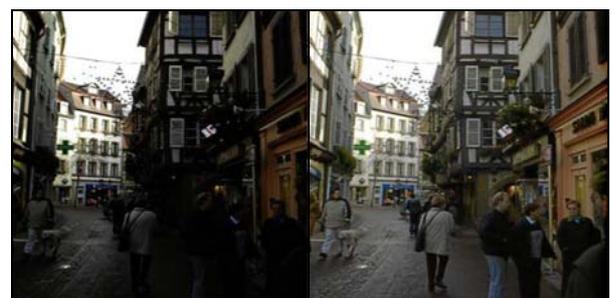
Global image enhancement

These are enhancement stages acting on the whole image. Every image pixel is changed. The stages are:

Stage 1. Colour cast removal in the shadows, midtones and highlights. Modern algorithms can also correct non linear exposure dependent colour casts which are different in shadows or highlights.

Stage 2. Contrast enhancement made by shifting the black point and the white point of the image. The contrast is nearly always stretched.

Stage 3. Density correction of the image.

Stage 4. Saturation enhancement of the image.

Stage 5. Sharpening of the image using traditional unsharp masking methods.

Local image enhancement

This is a relatively new way to enhance an image which becomes more and more important. Newest digital cameras already produce images which show nearly perfect exposure. Global image enhancement algorithms can not much improve these images anymore. However it is amazing to see what improvement can still be made using local image correction.

1) Local shadow enhancement can drastically improve images where important details disapear in the shadows. This is the case of a great percentage of images and the improvement is quite spectacular in some cases.

Original Image   Shadow enhanced image

Figure 7. Example of local shadow enhancement

2) Local highlight enhancement tries to preserve and enhance details in the highlights. Flash heads are improved and snow still shows structure and is not just flat white.

3) Memory colour enhancement is based on the detection of important colours in the image. The most important memory colours are skin, vegetation and blue sky tones. Tests have demonstrated that in most cases people detect colour casts only in the skin tones because this is the most important colour for which we always have a reference in mind.

| Original image | Memory colour enhanced image (skin tone / vegetation) |

Figure 7. Example of local memory colour enhancement.

A good example of the advantage of local colour correction are pictures shot at mixed light conditions. In this case a person can be illuminated by the camera flash while the room in the background is illuminated by fluorescent light.

Using only global colour correction you can correct well the greenish cast of the background but you will make the skin tone look magenta. You also may decide to colour correct the skin tone but then the background remains greenish. Correction of both colour casts using traditional colour correction is impossible. Using local correction, the colour cast of the background is corrected using an automatic algorithm. The magenta skin tone is now locally corrected using local memory colour correction.

4) Local sharpening only sharpens parts of an image. Vegetation is for example sharpened more then skin. Sky is not sharpened to avoid visible noise in the sky. Dark shadows are even smoothed to remove thermal dark noise.

Local image enhancement algorithms can further improve already well balanced images. To achieve this type of local image improvement using image editors like Photoshop is very difficult and time consuming. It is a competitive advantage for the lab to be able to offer this type of automatic image enhancement to the customer.

The Q-enhancer hot folder image processing software

With Q-enhancer Colour-Science offers a simple hot folder image processing software which can enhance images and convert them into the printer colour space using ICC profiling.
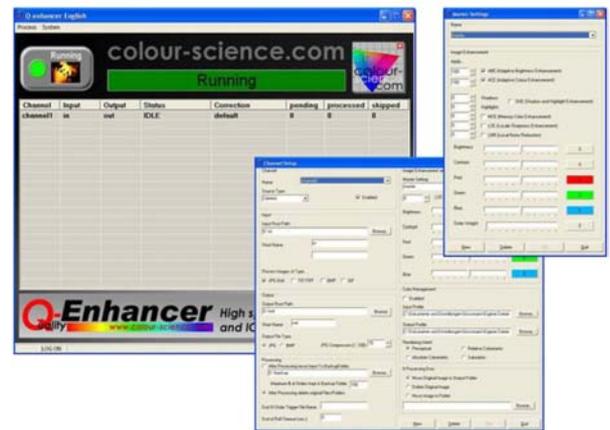

Figure 8. The Q-Enhancer hot folder image processing software

For the production you will need to put the Q-enhancer software in front of the printers. Q-enhancer lets you define printing channels using hot-folders. This way you can automatically route folders with image orders including order information to the right printer. Q-enhancer will automatically convert the images using a generic ICC input profile and a printer specific ICC output profile.

For professional work i2e image enhancement will be turned off. This way the professional photographer gets exactly the result he would get on his profiled proofing printer. Q-Enhancer is fully automatic and needs no further attention.

Conclusion

By using a combination of image enhancement and printer profiling in the labs we have obtained a system which will produce the same image quality on any good printer.

Before this we always had the problem that customers tested our image enhancement on unprofiled and sometimes badly calibrated printers. This way the print results have always been different.

Now by printing enhanced images on profiled printers we exactly know how the results will look. This is good for us, but even better for big photo-finishing groups because they now have for the first time a solution enabling them to print the same images in all their labs on any equipment with exactly the same result.

From this time image quality is not any more a variable dependent of equipment or the operators who operate or calibrate the printers. Quality becomes now a constant which can be easily reproduced and monitored.

Biography

Frank Grossmann studied Microtechnics at the Federal Institute of Technology in Lausanne and Business Administration at the Federal Institute of Technology in Zurich. After the Studies in 1989 he founded Labocontrol AG which became quickly a leading producer of quality control tools for analog printers and minilabs.

He was mainly responsible for the development of the Labocontrol/Digital Now high speed film scanners used for the production of Photo CD's. In Mai 2002 he founded Colour-Science AG which specializes in the development of digital image enhancement algorithms, colour management software and quality monitoring tools.

Walter Kraft studied Electronics at the Federal Institute of Technology in Zurich. He received the Dr. Sci. Techn. degree from the same University in 1984.

His current interests are in digital image analysis, classification, processing and enhancement. Before joining Colour-Science AG in 2003, he was with Gretag Imaging AG, where he designed the colour and density correction systems of three generations of printers: the first real high speed printer (the Gretag 3241), the hybrid Syntra Printer with Eye-Tech-Scanning and lcd local contrast correction, and finally the fully digital Cyra system.