# ICC Profile Based Defect Simulation

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## Abstract

*Standard accelerated lightfastness testing, when applied to output from today's generation of inkjet printers often produces estimates of over 100 years before typical light exposures will unacceptably degrade photographic-quality prints. However, these print longevity estimates do little to summarize the sort of changes that occure before failure criteria are met, and they provide an insufficient indication of the visual appearance of a print at the point of failure. Many ink-jet customers, including professional photographers, would be more confident in using a particular print system (device, ink and paper) if they could accurately visualize how their prints will look after a certain number of years of light exposure. Then they could decide for themselves if a print is still acceptable or not. We have developed a method that enables a visualization of the appearance of a print at various levels of light exposure upto and beyond the time where lightfastness failure would be predicted to happen. The method uses specially created ICC profiles. The simulations can be viewed on a calibrated monitor, or for a more accurate representation, printed on the particular printer-ink-paper combination in question. This technique can also be extended to simulate other defects, like how a color image appears to an individual with impaired color vision. Overall, the technique enables printer manufacturers, paper manufacturers and third parties to provide ICC defect simulation profiles that allow customers to assess the appearance of a print in the distant future. This is a capability that simply does not exist at the moment and that could be quite compelling, expecially to professionals who earn a living with their prints.*

## Introduction

ICC device profiles have traditionally been used to transform color data specific for one device into another device's native color space [1]. Within an open color management architecture, ICC profiles enable the unambiguous communication of color data between different devices, operating systems, and companies.

The core of our solution is to use the ICC profile format, data structure and architecture not only to manage the way in which colors are communicated and reproduced on different devices, but also to simulate the changes that will happen to the appearance of the printed image over time, or to simulate how the printed image will be perceived by different subgroups of the population. Lightfastness and color deficiencies are two non-exclusive examples.

## Current Solution

Today, printer manufacturers publish one number to represent how long prints from a particular printer-ink-paper combination are supposed to last. This is based on accelerated fading of a target print to the point at which the changes exceed given thresholds, like those specified by ANSI/ISO [2] and/or the Wilhelms Institute [3]. Users are then expected to accept this number as an accurate indication of how long their prints will last. However, if they want a better idea of what happens to their actual prints after a long period of time (say 50 years), they either have to wait 50 years to see what happens (highly unlikely), or they have to send their print for accelerated fading to see the effects (very expensive and also time consuming).

## Proposed Solution

The proposed solution is to provide a set of ICC profiles that simulate the appearance of a print after some discrete number of years (ten, fifty and a hundred years, for example). Those profiles can be used in a similar manner to normal ICC profiles, and the professional user can either print a fade-simulated image on the same paper with the same device, or he can preview the faded image on a calibrated monitor. Based on the results, he can make a more educated decision about the choice of printer, ink, and paper for the reproduction of a particular image. Printer-ink-paper combination A might be fine for image one within a selected time frame, but printer-ink-paper combination B might be superior for another image and another time frame. Furthermore, the lightfastness index might be low, but the expected fade might not be a problem for a particular image. Professional photographers often like the look and feel of a particular paper, which might have low lightfastness numbers. In that case, a simulation might help them to decide whether or not to use the paper despite the lower lightfastness numbers. Furthermore, lightfastness and image stability of inkjet prints is one of the most wide spread concerns of professional photographers and potential buyers of their art.

As mentioned above, the types of defects that can be simulated through the use of an ICC profile and which are helpful for a user are quite broad, ranging from changes that will happen to an image over time if it is stored in high temperatures, under glass, or under dark, to name a few.

## Generation of ICC Profiles to Simulate Image Degradation

*Figure 1* depicts a common flowchart used to generate a traditional ICC profile, and *Figure 2* shows the modifications necessary to generate a set of simulation profiles. This example uses lightfastness as the image degradation to be simulated. A test chart that adequately samples the printer color space is printed and measured. The chart is then subjected to an accelerated fading process. As the test chart is being faded, the reflectance properties of the color patches change. To monitor the behavior of the fading process, the chart will be re-measured in regular intervals, typically once a day.

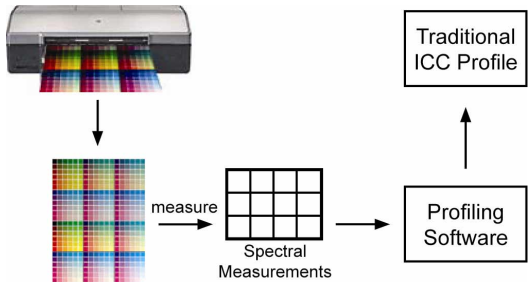


***Figure 1**. Flowchart detailing the generation of a traditional printer ICC profile.*

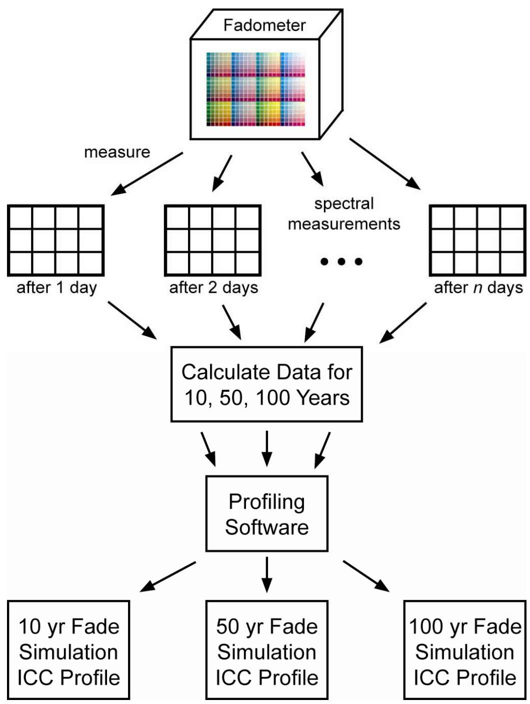


***Figure 2**. Flowchart detailing the generation of a fade simulation ICC profile.*

Within our new process, the collected data set will be used to calculate reflectance functions corresponding to a discrete set of time intervals for which profiles will be calculated. Different methods can be used for that. Linear interpolation is the most straightforward, but least precise method. For the results presented in this paper, we choose curve fitting over data interpolation for modeling the spectral reflectance of each patch at each of the light exposure levels of interest. The fitting algorithms greatly reduce the impact of noise in the raw measurement data. Traditionally, different charts are used to perform lightfastness tests, but they are also measured once a day. Thus, the proposed method does not require additional steps. The pairs of device dependent values and device independent values corresponding to a fading of x years are used within standard profiling software resulting in a set of fade simulation ICC profiles. The workflow depicted in *Figure 1* is a common workflow for generating an ICC printer profile. Both profiles will subsequently be used.

## Use of the ICC Degradation Profiles

Having generated ICC simulation profiles for a series of years of image degradations and for a series of devices, a user can apply those profiles within any software application, which supports the ICC framework. *Figure 3* depicts as an example the application of a lightfastness profile simulating the fading that takes place after a print is left out for a period of 100 years. Instead of relying on a generic description of the fading process, the user can directly visualize the anticipated effects for the specific image, the specific paper and the specific printer. Certain defects might show up in a specific image to a stronger or lesser degree. In this example, a source sRGB image is transformed into a printerRGB space using the standard sRGB profile as the source and the actual printer/paper profile as the destination profile. At this stage, the image can be printed if a normal print is desired. To simulate the effects of fading, the fade simulation ICC profile is assigned to the image. Once this profile is assigned, the image will desaturate, and a calibrated monitor can be used to preview the results. If a hard copy proof is desired, the fade simulation ICC profile can be used to transform the image to the device independent space (Lab of XYZ), and then the normal printer profile can be used to transform back to device space, using the absolute colorimetric intent in both cases. The image is now ready to be printed.

## Discussion of the Proposed Solutions in Terms of the State of the Art

The authors are not aware of any printer and or paper manufacturing company or third party that currently offers ICC defect simulation profiles to end users. However, a literature survey revealed that Bror Hultgren presented a paper at this year's Electronic Imaging Conference [4], where he talked about the idea of modeling imaging system behavior and simulating the behavior by using ICC profiles, an idea which we have not seen anywhere else when we began work on this topic. He also talked about modelling fading, but in his paper he did not discuss how profiles can be generated from real faded data nor how a profile like that would be used. It is important to use it correctly, as depicted in *Figure 3*. That methodology can also easily be validated by comparing an image, which has actually been faded with a print of a simulation. The authors are planning to do exactly that in time for the final presentation. Furthermore, this paper also discusses a way how anyone who is currently performing print defect tests could very easily provide ICC defect simulation profiles to the end-users.

## Implementation of a Prototype

In order to demonstrate the feasibility of the discussed method, we faded 3 different targets

- a $10^3$ RGB target printed on inkjet printer #1 using paper A
- a $10^3$ RGB target printed on inkjet printer #1 using paper B
- ECI 2002 CMYK target printed on inkjet printer #2 using paper C

While these three targets were being faded, we performed spectral measurements once a day until well beyond their lightfastness fading point (up to an equivalent of 50 years in the first two cases and up to an equivalent of 100 years in the third case). Using these measurements, we calculated the following lightfastness ratings according to the ANSI/ISO criteria:

- inkjet printer #1 with paper A : 3 years
- inkjet printer #1 with paper B : 30 years
- inkjet printer #2 with paper C : 55 years

*Figure 4* contains simulations for a particular image for the 3 different printer/media combinations for 0, 30, 60 and 90 years, whereby the images were color managed for a SWOP CMYK output device. Although an image may look quite similar on each of the different printer/media combinations immediately after printing, the differences increase dramatically as times goes on. It is also interesting to see the differences in the fading process as well as the fact that the image looks quite acceptable for printer #2 with paper C after 90 years although its lightfastness was calculated to be only 55 years. From the data collected, we can calculate profiles for any number of years that we are interest in.

## Conclusion

We have developed a system which uses the ICC color management system to simulate image degradation, such as the fading of a print over time. Such a system enables the user to immediately visualize the effects of such image degradations for their particular piece of work and for a particular printer-paper combination. Naturally, the results are dependent on the quality of the modeling of the image degradation and how well the actual storage conditions correspond to the assumed ones. The same caveats hold true for lightfastness ratings provided today. This is still an area of active research. From an end-user perspective, anyone familiar with ICC profiles will feel comfortable using these simulation ICC profiles. Again, lightfastness was used as an example, but the same techniques can be applied to any modification that can either be measured or modeled.

We are confident that simulation ICC profiles would be extremely valuable to professional photographers and other users who want to produce prints intended for long-term display or storage.

## References


[1] ISO 15076-1:2005, Image technology, colour management – Architecture, profile format and data structure – Part 1: Based on ICC.1:2004-10, http://www.color.org

[2] ISO 18909:2006, Photography – Processed photographic colour films and paper prints – methods for measuring image stability.

[3] Henry Wilhelm, Carol Brower, "The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures", Preservation Publishing Company, 1993.

[4] Bror Hultgren, "The Use of a Virtual Printer Model for the Simulation of Imaging Systems", Proceedings of SPIE-IS&T Electronic Imaging, SPIE Vol. 6059 – Image Quality and System Performance III, 2006.


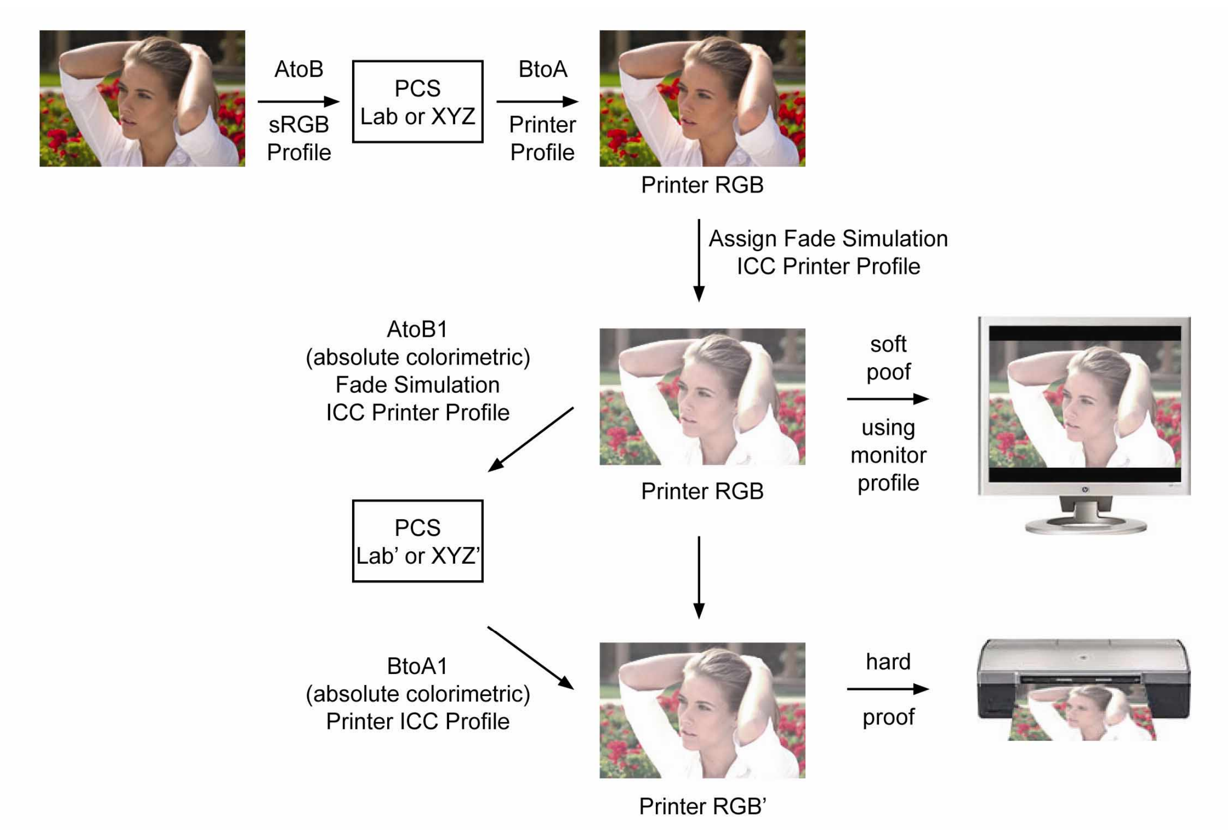


***Figure 3**. Flowchart depicting the use of a fade simulation ICC profile to simulate the appearance of a print after 100 years.*

***Figure 4***. *Color simulations (generated for a SWOP CMYK output device) of how an image will look like after 0 years (column 1), after 30 years (column 2), after 60 years (column 3) and after 90 years (column 4) for an image printed on inkjet printer #1, paper A (row 1), inkjet printer #1, paper B (row 2), and inkjet printer #2, paper C (row3).*