

# ICC Profile-Driven Adaptive GCR for High-Fidelity Facsimile Reproduction of Music Manuscripts

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## Abstract

*The faithful reproduction of historical art and music manuscripts lies at the intersection of color science, printing technology, and artistic interpretation. In such projects, the printed facsimile must be visually indistinguishable from the original, both to the trained eye and to the casual observer. This paper presents a methodology for creating dedicated ICC profiles for high-fidelity facsimile printing, developed through over a decade of reproducing Fryderyk Chopin's manuscripts. The approach is based on adaptive Gray Component Replacement (GCR), selectively tuned to different tonal and chromatic regions to preserve fine details, control local contrast, and mitigate issues such as show-through caused by the transparency of original paper. By mapping GCR levels according to the specific visual characteristics of each work, the method allows for targeted control over critical features such as ink density, edge sharpness, and tonal transitions. The process also accounts for substrate variability, press condition, and metamerism effects under different illuminants. Results demonstrate that adaptive GCR, combined with context-driven communication between technical and artistic stakeholders, enables reproductions that maintain the visual fidelity, texture, and emotional impact of the original works.*

## Introduction

Art reproduction lies at the intersection of several disciplines — color science, printing, and art.

In most cases, the recipients of such work are individuals viewing the print from an artistic or historical perspective, expecting that every detail they perceive is intentional and faithfully mirrors the original — or, in some cases, being unaware that they are looking at a replica at all. Yet every emotional response evoked in the viewer must be grounded in rigorous technical work, in a manner akin to performing an analog-to-digital conversion of impressions and feelings.

This paper presents a methodology I have developed for creating dedicated ICC profiles for the printing of specific works of art. The approach is the result of over ten years of experience in producing dozens of high-fidelity facsimiles of Fryderyk Chopin's manuscripts.

## Origin of the Problem

### Digital reproduction and transparency

Music manuscripts are typically loose sheets of varying sizes. They are digitized using medium-format digital backs, with each sheet captured as a single image. This results in varying pixel density per centimeter of the original, though the high quality of the capture device ensures that the files remain of excellent quality.

A recurring problem is the low thickness — and thus partial transparency — of the original sheets. The manuscripts, often around 200 years old, show signs of smudging, wear, folds,

imprints, and the effects of long-term storage. The most significant issue is show-through from the reverse side. When photographing one side, bleed-through from the other is inevitably captured. Furthermore, when printed on thin paper — itself slightly transparent — darker elements from the reverse side may naturally become visible on the front. Thus, printing directly from source images without adjustment results in reproductions where unwanted show-through alters the intended appearance.

### Fine details

Subtle textual and musical notations are of great importance. Pianists and researchers often interpret the composer's intent and mood from the very strokes of his hand. This makes precision in the reproduction process critical to preserving the informational and artistic value of the manuscript.

### Density and local contrasts

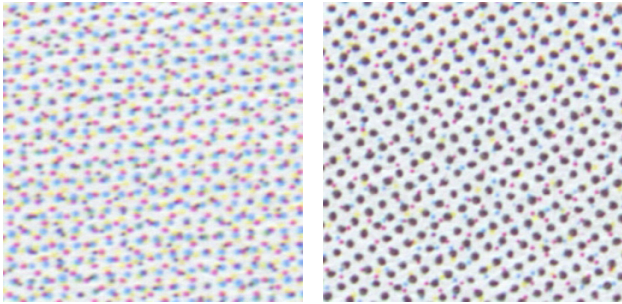
The originals were created with the tools and materials available at the time, each with distinct characteristics — such as the density and hue of fountain pen ink, or the natural color and texture of paper in combination with printed or drawn staves. While these differences may seem obvious, in printing all elements originate from a single imaging process with a fixed gamut. This often requires the ability to distinguish between elements not only in color but also in the manner in which they were originally produced.

### Perceived Visual Fidelity

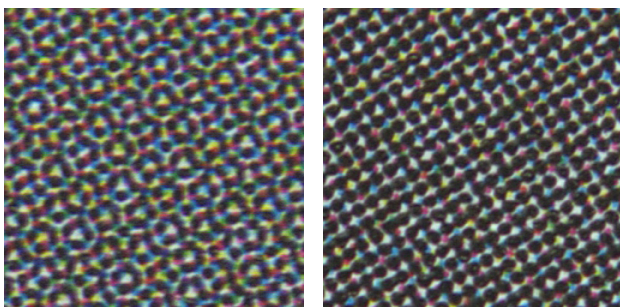
The ultimate goal is to produce reproductions that, when placed beside the original, are indistinguishable from it. This means that all technical aspects — including screen ruling, halftone dot shape, rosette formation, FM screen grain, and any printing process artifacts — must be hidden or minimized so as not to interfere with perception.

## Effect of GCR on the Image

The Gray Component Replacement (GCR) technique aims to replace the neutral (gray) portion of CMY colors with black (K) across the entire tonal range, rather than only in the darker regions. This approach has several advantages; however, it can also introduce increased graininess in neutral tones or make rosettes in amplitude-modulated (AM) halftone screens more pronounced. One potential benefit of this technique is the sharpening of edges in more detailed areas of the image.

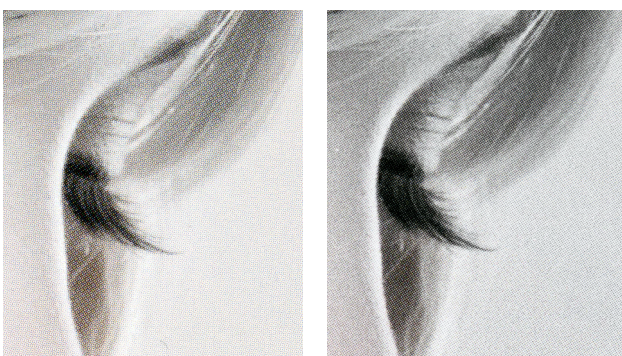


**Figure 1.** Comparison of a light tonal area rendered with minimal GCR (left) and high GCR (right).



**Figure 2.** Comparison of a dark tonal area rendered with minimal GCR (left) and high GCR (right).

The examples above illustrate not only the varying levels of black channel usage, but — more importantly in this case — the additional patterns that emerge depending on image lightness and the selected GCR level. In lighter areas, the black channel tends to introduce visible grain, while in darker regions, reduced black usage can lead to the formation of rosettes.

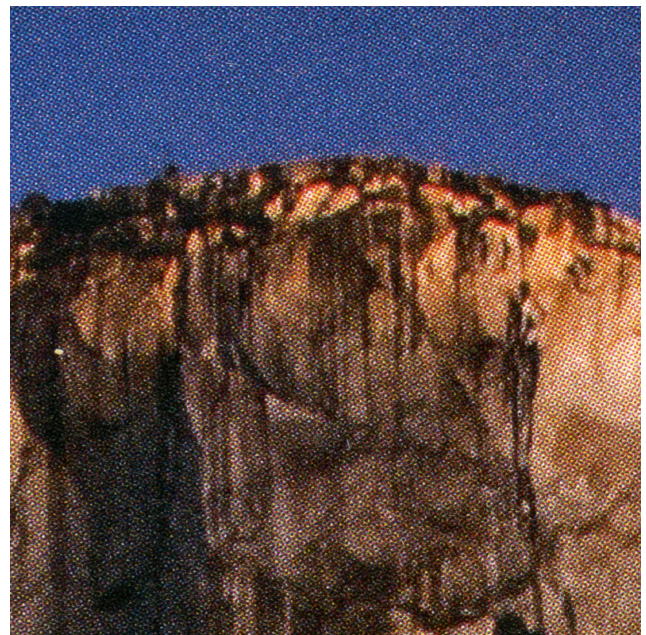


**Figure 3.** Comparison of two images using conventional GCR — minimal GCR on the left, maximum GCR on the right.

Producing a visually attractive print makes it difficult to adopt a single GCR level across the entire image. A visual comparison of several prints with different fixed GCR levels reveals that each performs well in certain areas while showing weaknesses in others.



**Figure 4.** Image with conventional GCR.

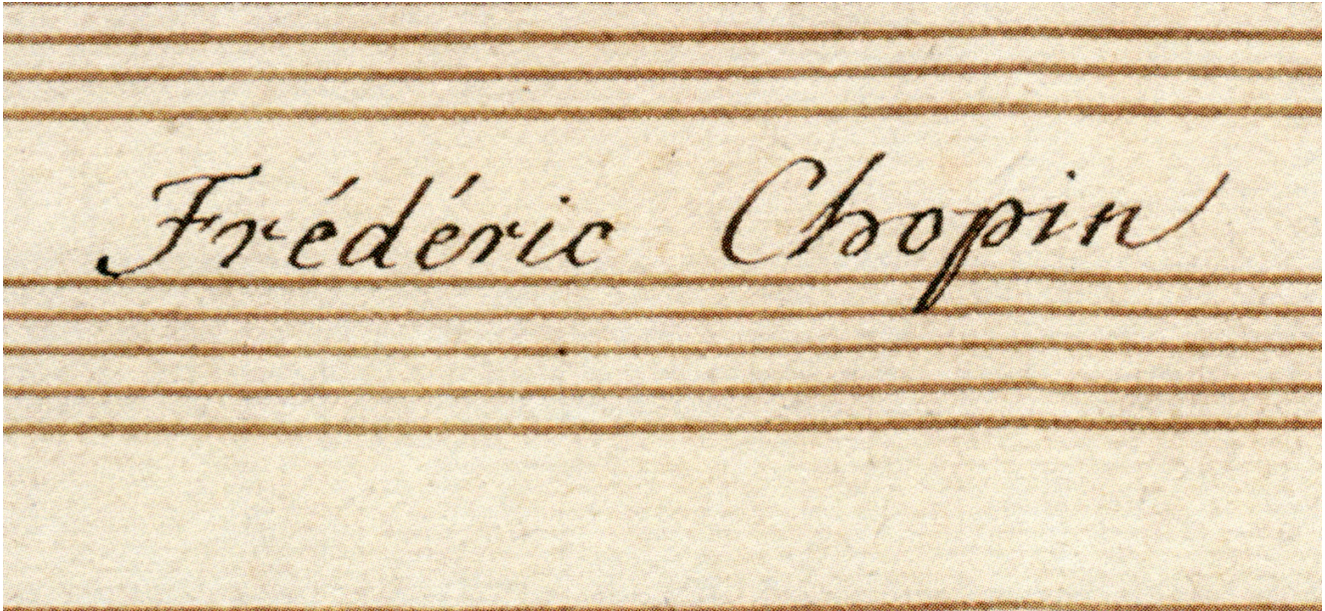


**Figure 5.** Image with adaptive GCR.

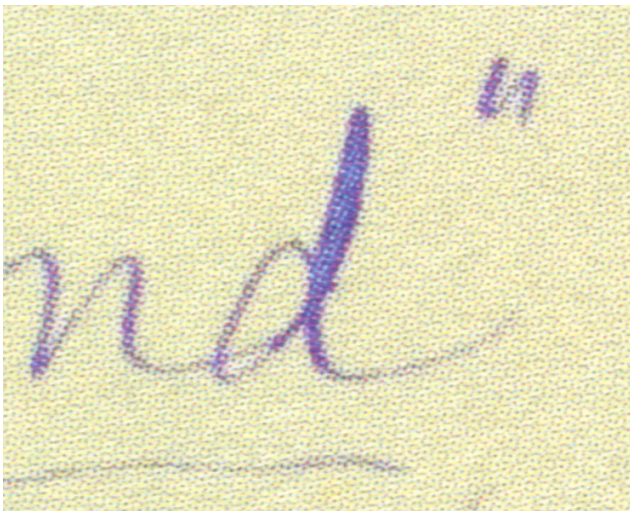
Based on the comparison of Figures 4 and 5, note the edge sharpness in the scale as well as the smoothness of uniformly colored elements. It can also be observed that certain areas of the image share the same GCR level in both prints, resulting in an unchanged visual effect. An ICC profile is a set of tables of defined size — and thus a defined addressing precision — that map specific input values to specific output values. Based on this property, I began my work by identifying distinct regions within the reproduced document and



interpretation. However, the GCR function is inherently three-dimensional and equally dependent on the L\* channel level. Given that printed images have a limited color gamut, my adjustments are likewise restricted to areas where such modifications are necessary.



**Figure 10.** A scan from the print showing multiple GCR levels: very high for the inscription to preserve sharp edges, medium for the staff lines to convey a sense of higher chroma, and varied for the background depending on color purity.



**Figure 11.** A scan from the print where GCR was disabled to enhance the edge sharpness of the blue inscription. This corresponds to the curve shown in the charts above.

## Communication

In commercial printing, we rely on terminology that enables precise and actionable responses — such as  $\Delta E$  values for specific print patches or the adjustment of spot colors. In the reproduction of

historical prints, however, the feedback is often expressed in more poetic than technical terms: *insufficiently expressive*, *too bland*, *subtler background*, *overly harsh appearance*, and so forth. Each of these descriptors is important and can be translated into measurable parameters, but their interpretation depends heavily on context.

I have observed that each project demands a different approach, accompanied by its own vocabulary, and often requires preparing separations in such a way that press-side adjustments are possible. For example, when there was a need to enhance contrast or darken specific areas — such as the musical notation itself — I was able to control a single separation channel directly on the press. This requirement arose multiple times in response to differences in local contrast between the original and the reproduction.

It is worth noting that although color rendering is performed using relative colorimetric adaptation, the density of black is often insufficient for certain substrates. This issue is addressed by manipulating the single channel carrying the relevant information.



**Figure 12.** Separation of GCR elements with different chroma and hue levels but similar lightness.

The previously mentioned issue of show-through between recto and verso due to paper transparency is also addressed here. Proofs from digitization facilities are typically produced on thick, fully opaque substrates, so the problem only appears during final printing. Because these are image regions with known lightness, saturation, and chroma ranges, I can transfer much of the content to the black channel and then non-linearly reduce ink coverage in those regions. This provides control over the initial printed image and allows for press-side corrections if needed.

### Other Challenges and Opportunities

The process described here does not encompass the entire scope of reproduction work, yet the mechanisms presented enable a high degree of control over the final image. For certain projects, the black density achievable in a single pass is insufficient, necessitating an additional pass.

It is important to mention that precise proofing on the target press can take several hours and requires a machine in excellent technical condition. Due to the specificity of this printing process, ICC profiles are created not only for the given *press + paper* combination but also tailored to the exact condition of the press at the time of printing, compensating for its unique limitations.

Another challenge — which I also address when using a minimal GCR level — is metamerism between the reproduction and the original. Based on a series of measurements, I am aware of the color shifts present in archival materials as well as the realities of modern printing technology. The most common intended viewing light source for the final reproduction is illuminant A; therefore, I evaluate colorimetric relationships under both D50 and A, aiming to minimize color deviation. Nonetheless, the highest priority remains maintaining the *shape fidelity* of the print.

Finally, screening methods have not been discussed in this paper by design, as this subject entails additional considerations in GCR adaptation and often necessitates alternative separation strategies, which fall outside the scope of the present discussion.

### References

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### Author Biography

*Marcin Dąbrowski is a color scientist and print technologist with expertise in ICC profiling, adaptive GCR, and multi-channel printing. At HP, he developed 7- and 5-color printing systems incorporating Light Light Black for extended tonal control. He later established a color science laboratory in the cosmetics industry, creating precision workflows for pigment formulation and evaluation. His work bridges color science, imaging, and materials engineering to achieve uncompromising visual fidelity in printed reproductions.*