

Computational Alternative Photographic Process toward Sustainable Printing

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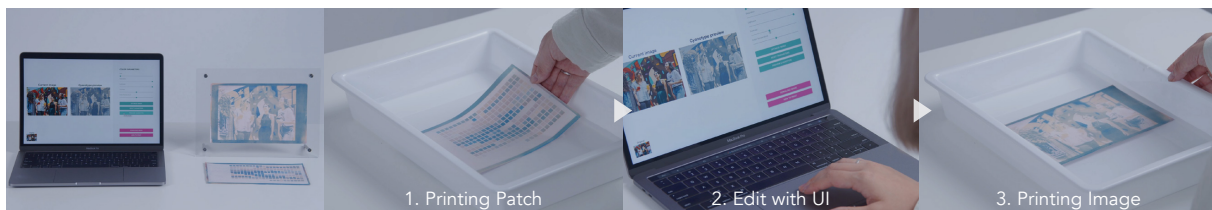


Figure 1: Computational framework for tri-color cyanotype, in which the normal cyanotypes are stacked in three layers. Data-driven simulation is enabled based on color patch measurement, and image adjustment is performed using the UI.

ABSTRACT

We propose a computational alternative photographic process that integrates computer processing with the conventional printing method, particularly cyanotype. Cyanotype is a non-silver-halide process that has a lower environmental impact and is known for its availability to produce tri-color prints; however, the tri-color process is complex and time-consuming. To simplify this heavy printing process, our framework provides a user interface for image editing and optimization based on color simulation within a printable color gamut. We demonstrate image editing and tri-color cyanotype printing using our framework, indicating that it can reduce the number of user trials and errors.

CCS CONCEPTS

• **Applied computing** → **Media arts**; • **Human-centered computing** → **Visualization toolkits**.

KEYWORDS

Alternative Photographic Process, Cyanotype, Data-driven Simulation, Optimization

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1 INTRODUCTION

Alternative photographic processes have a long history of more than a century and provide a unique aesthetic look that has fascinated many people, from hobbyists to artists [James 2015].

In graphics communities, the diverse media expressions in the real world have prompted attempts to reproduce these expressions in digital images. For example, Newson *et al.* constructed a stochastic film-grain model to reproduce the noise in film photography [Newson *et al.* 2017]. Wang *et al.* developed an image filter to reproduce watercolor painting expressions [Wang *et al.* 2014]. Echevarria *et al.* proposed physically and chemically based simulations of alternative photographic processes [Echevarria *et al.* 2013]. We also established a simulation method for reproducing the alternative photographic process expression on a computer; however, it is significantly different in that we focus on introducing such simulations into the actual printing process.

There are various types of alternative photographic processes, such as the daguerreotype [Saltzman 2015], calotype [Greene 2002], and cyanotype. The cyanotype, that was developed by Sir John Herschel in 1842 [Herschel 1842], was the first successful silver-free photographic printing method. It combines iron (III) ammonium citrate and potassium ferricyanide as a photosensitizing agent; only iron liquor is used for waste liquid treatment. Hence, this process

has a lower environmental impact and can help achieve environmental sustainability. Because of its simplicity and affordability, it has been used for a long time as a method for reproducing architectural drawings [Mar 1887]. However, similar to other alternative photographic processes, this process is limited to monochrome printing (only blue) and has a narrow printable color gamut.

The tri-color cyanotype is a printing method that produces colorful photographs using an alternative photographic process that is produced by layering tone-tuned cyanotypes in three different colors (e.g., cyan, magenta, and yellow). Although the technique for multi-color but limited color gamut cyanotypes has existed [Fossen and E 2020], a more colorful printing method was introduced by Annette Golaz in 2021 [Golaz 2021]; she studied the botanical-based tri-color cyanotype with great enthusiasm. This technique revolutionarily expands the color range of alternative photographic processes; however, the developing process becomes extremely complex (*i.e.*, the number of adjustable parameters considerably increases), and the time required to print a single sheet significantly increases, making the trial-and-error process difficult.

To address these issues, we propose a novel computational alternative photographic process. This study makes alternative photographic processes easily accessible by integrating computational processing into the printing process. Our framework consists of three main steps: (1) printing and measuring color patches, (2) editing or optimizing an image using our user interface (UI) with data-driven simulation, and (3) printing the edited image. We demonstrated how our framework can print tri-color cyanotypes and simplify the adjustment process. This demonstration suggests the effectiveness of integrating simulation-based editing/optimizing with printing processes, and even novice users can easily print tri-color cyanotypes.

2 TRI-COLOR CYANOTYPE PHOTOGRAPHY

Cyanotype is toned by reacting an alkaline precipitate with an acid, such as tannic acid or gallic acid, to change the developed color¹. It was developed because people did not like the peculiar color of blue. The expression became richer by removing the constraint of a single blue color. For example, immersion in sodium carbonate after development can turn the image yellow, while exposure to red wine or jasmine tea can add dark depth and astringency to the developed blue color (Figure 2).

The tri-color cyanotype is an alternative photographic process that produces three-color prints by simply overlaying the toned cyan, magenta, and yellow. Golaz, a Swiss photographer, published works on tri-color cyanotypes and their printing methods [Golaz 2021]. The conventional cyanotype method was used as a single-layer process. Similar to the gum bichromate printing, multiple coatings can be applied to a single print; hence, we repeatedly printed single-toned colors to reproduce a three-color print (Figure 2).

The tri-color cyanotype uses chemicals such as citric acid and madder roots, in addition to the basic elements required for the conventional cyanotype. The single-layer printing process was repeated three times. The first layer was toned to magenta using

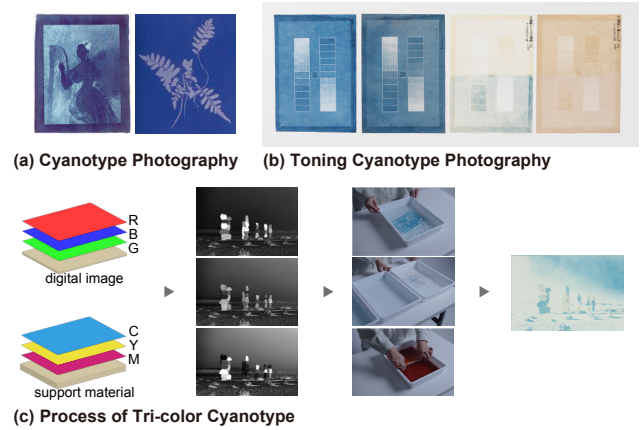


Figure 2: Examples of cyanotypes, toning (developing only, dark green tea, sodium carbonate, and grape tea toning), and the printing process.

madder roots, the second layer to yellow using sodium carbonate, and the third layer to cyan using water development and sodium carbonate bleaching (see Supplemental Materials for details).

3 FRAMEWORK

3.1 Overview

Our proposed framework uses a simulation-integrated UI to print tri-color cyanotypes efficiently. Figure 3 depicts the overall framework. First, the user must print a color patch and measures the RGB values to enable simulation. Next, the image to be printed is edited or optimized using a simulation-integrated UI. Finally, the image is printed after the user approves of the edited version. Thus, the user only needs to print the patch and the image twice with our framework.

3.2 User Interface

The UI of our framework was implemented as a p5.js²-based web application, as shown in Figure 1 (c). The UI contains three components: a parameters editor for image tone tuning, a print preview button, and an image-optimization button. Users can adjust the image's hue, saturation, lightness, and contrast, and they can preview the simulated result of the tri-color cyanotype print of the edited image based on the prediction model (described in subsection 3.3). In addition to the parameter adjustment, users can get the image optimized for the printing result to be closer to the original image data within the printable color gamut. The optimization process is described in subsection 3.4.

3.3 Prediction Model

We implemented a tri-color cyanotype simulation for the editing UI. In this simulation, a target color patch called TC2.83 (294 patterns) is first printed and measured to obtain the training data for the prediction model. During data collection, the printed patches were

¹<https://static1.squarespace.com/static/5ac4eb022971149bb6d709d3/t/5b05a0eb562fa7dc52bcae7c/1527095532169/Toning-Cyanotype-Prints.pdf>

²<https://p5js.org>

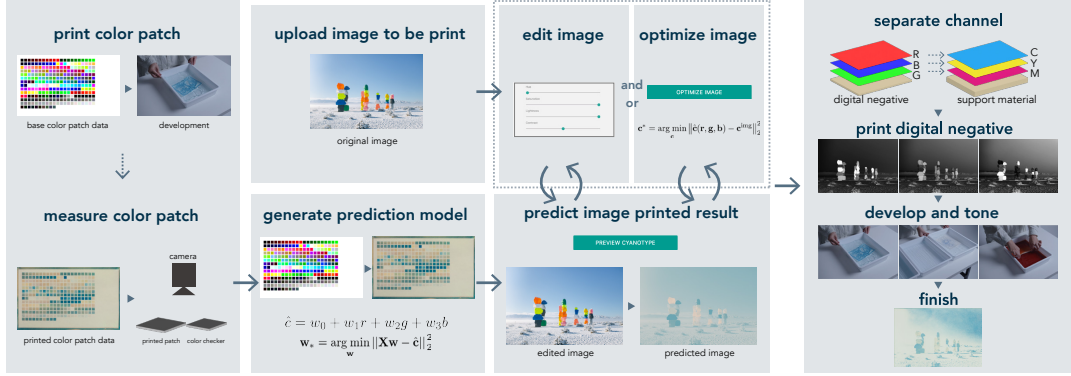


Figure 3: Tri-color cyanotype printing framework with integrated computer processing processes. It can simulate printing results of tri-color cyanotype and optimize printing results of tri-color cyanotype using data-driven inference.

photographed together with the x-rite's ColorChecker® to perform color correction and measure the RGB values.

After measuring the color patch data, the training data and linear regression model were used to build a prediction model (Figure 3). For example, to determine the predicted color value, \hat{c} , using a linear regression model, the following equation can be used:

$$\hat{c} = w_0 + w_1r + w_2g + w_3b, \quad (1)$$

where r, g, b denote the original digital values, and w_i denotes the coefficient for the color value prediction.

To use such a linear regression model, the coefficient w_i needs to be optimized. The optimal coefficients w_* are derived by solving the following optimization problem:

$$w_* = \arg \min_w ||Xw - \hat{c}||_2^2, \quad (2)$$

where original patch values $X = [1, r, g, b]$, measured patch values $\hat{c} = [c_0 \cdots c_n]^T$, and coefficients for color value prediction $w = [w_0, w_1, w_2, w_3]^T$. To construct this model, we used scikit-learn³.

3.4 Optimization towards Target Image

Although users can edit images using our UI, we suggest image optimization to make obtaining the best printing results easier. In this optimization, we sought to obtain the printing result as close to the target image as possible within the printable color gamut. To derive the optimal color values c^* , the following optimization problem was solved:

$$c^* = \arg \min_c ||\hat{c}(r, g, b) - c^{img}||_2^2, \quad (3)$$

where c denotes the RGB values of the image in each iteration and c^{img} denote the RGB values of the target image. We used TensorFlow⁴ for the optimization process.

4 RESULT

In our framework, the tri-color cyanotype is printed using prediction and optimization as the core technology. In this section, we will show the results for each. First, we describe the prediction results. As shown in Figure 4(a), the image color prediction is realized based on patch measurement data. The actual printed result (image 4) shows that the blue color is not printed well, but the overall characteristics are consistent between the prediction and the print. Next, we describe the optimization results. As shown in Figure 4(b), it can be seen that similar results are obtained for the prediction and the printing even when optimizing. Furthermore, we can see that the optimized image has improved contrast. The PSNR value is improved before and after the optimization. Specifically, the PSNR of image 3 is 8.121, while the PSNR of image 5 is 8.894. Finally, Figure 4(c) shows the design results for various images and patches (i.e., the printing parameters change slightly). It can be seen that various images can be printed in tri-color.

5 DISCUSSION

Optimal setting parameters. Appropriate parameter settings are essential for obtaining good printing results (e.g., exposure time and developer soak time). However, in this study, the setting parameters were fixed. These fixed values were empirically determined from our pre-experiments, based mainly on Golaz's recipe [Golaz 2021]. Hence, there is potential for further improvements in this parameter determination. To optimize the parameters, it was necessary to compare the printing results repeatedly while changing the setting parameters. Once the optimal parameters are obtained, the color gamut is sufficiently broad to satisfy the user's wishes.

Print Color Stability. Our proposed framework assumes that the printing accuracies of the first patches and the final image are relatively similar. However, achieving the same printing characteristics twice is difficult. Inevitably, the printing characteristics will change depending on factors such as humidity and developer mixing, as shown in Figure 5. However, by fixing the set parameters, the essential printing characteristics can be unified; hence, the core contribution of the proposed framework is not significantly impaired.

³https://scikit-learn.org/stable/modules/generated/sklearn.linear_model.LinearRegression.html

⁴<https://www.tensorflow.org/>

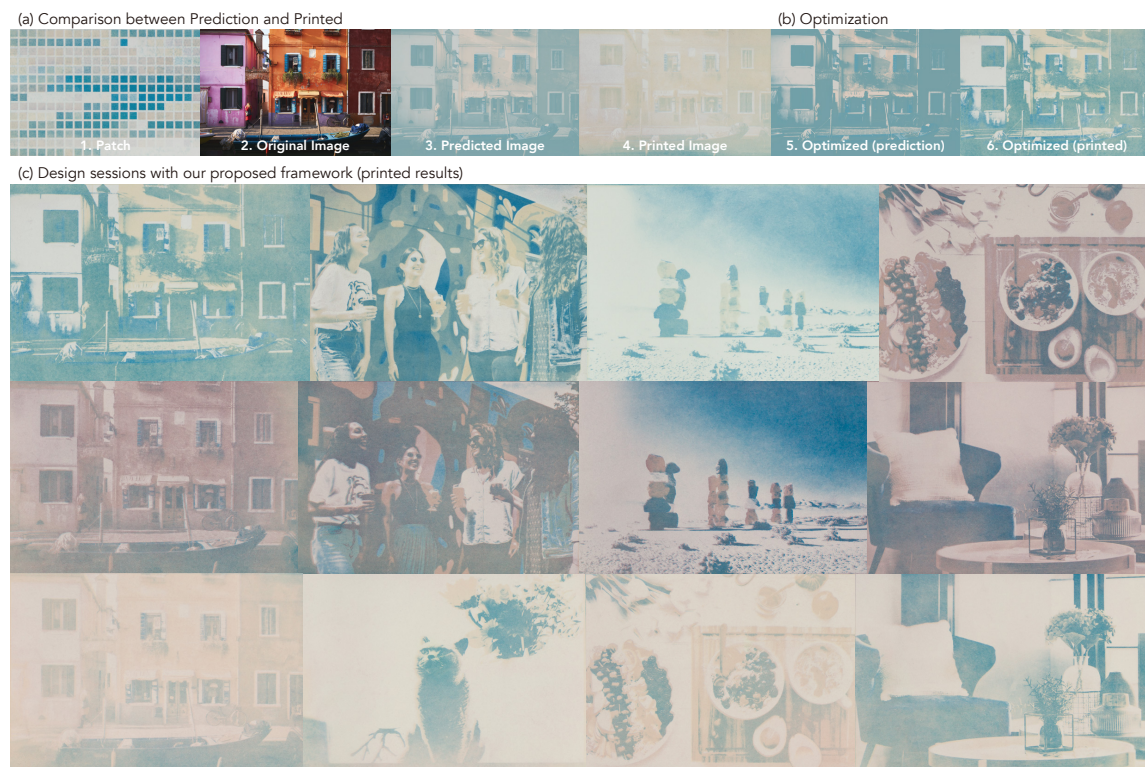


Figure 4: (a) Comparison of the predicted printing result of the original image with the actual printed one, (b) printed optimized image, and (c) design sessions using our proposed framework.

Simulation Accuracy. We chose the linear regression model for the simulation because it was reasonable in terms of simplicity and accuracy and was sufficient for our concept. However, considering nonlinearity may lead to improvements. In the future, we intend to consider models that can consider nonlinearity to achieve a higher-quality simulation.

Lack of User Study. We did not evaluate the UI through user studies. Figure 4 and supplemental materials demonstrate the usefulness of our UI (i.e., it is suggested that using our UI contributes to the ease of printing tri-color cyanotypes). Conducting user studies to further improve the framework in the future would be helpful.

6 CONCLUSION

We developed and demonstrated a data-driven simulation, image optimization, and UI for image editing that combines them for tri-color cyanotype printing. Our framework is expected to help simplify tri-color cyanotype printing, which conventionally requires many adjustment parameters and takes considerable printing time. We believe this study will open up new possibilities for alternative photographic processes toward sustainable print in graphics communities.

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Figure 5: Patches with slightly different colors each time.

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