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Digital Image Processing for Identification and Classification of Historic Photoreproductive Processes Used in Architectural and Technical Drawings Based on Color Analysis

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Abstract

This research explores the application of image color analysis techniques to identify and classify historic photoreproductive processes—such as blueprinting, diazotype, and other early photographic reproduction methods—based on the color signatures they leave on architectural and technical drawings. The objective is to develop a systematic approach for automatically detecting the specific process used in the reproduction of these drawings, which is critical for preservation, restoration, and analysis in historical studies.

Digital microscopy is employed to examine original 20th century photoreproductions from a historical technical company's archive in Greece. The processes examined are cyanotype, both positive and negative, diazotype of black and red color of line and Gel- lithography of black and brown lines. The visual features of photoreproductions are analyzed using computational pattern recognition techniques that emphasize the color of lines and type of printing process. The findings computational analysis are cross-referenced, and the resulting variables conclude the classification of prints, according to their colors. The results will contribute to the creation of an effective and accurate identification system for both photographic and photomechanical prints.

Introduction

Historic technical and architectural drawings were commonly reproduced using a variety of photoreproductive processes, each leaving distinctive color patterns and qualities on the final copies. These methods, such as cyanotype (blueprints), diazotype, and others, became widespread in the 19th and early 20th centuries. Identifying the photoreproductive process used is not only important for dating and classifying historical documents, but also for understanding the materials and techniques used in their creation.

While some of these processes are visually distinguishable to the human eye, the diversity and subtlety of the color differences in older prints pose a challenge for manual classification. Image analysis, particularly color analysis, offers an efficient and objective method for identifying and classifying these photoreproductive processes by analyzing the characteristic color signatures associated with each technique.

Overview of identification criteria for photoreproductive processes

In relevant literature, architectural photoreproductions are not classified as photographs, although, as processes, their origins and chemical principles are the same. This is a historic interpretation because they were developed in different trades; Construction companies between 1880-1930s were interested in using photographic principles to make accurate copies of architectural drawings and plans, with a focus given on ease of use, economy, and accuracy in reproducing images with lines without affecting the scale. [1] The used terms for their description are “Photoreproductions” and “Photomechanical Reproductions” [2].

Traditional methods for identification of the used processes rely on macroscopic and microscopic examination, alongside historical analysis. The traits examined are the color, surface texture and glossiness of the printed image and substrate amongst others. Contextual data may also include specific watermarks or backprinting evidence that are indicative of the process used. Few analytical techniques have been applied for the purpose of identification, on cyanotypes [3] and ferrogallic prints [4].

Price [1] provides the most comprehensive overview within the context of architectural archives. Additionally, Kissel and Vigneau [2] developed a flowchart to assist professionals, which is based primarily on visual examination. Further insights can be found in the study of Hans Scharoun archives, which culminated in a publication that includes a visual identification chart featuring magnified images captured in both normal and raking light, designed to assist scholars in their analyses [4], while the skills for visual assesment can be further enhanced by attendance of specialized seminars [5].

According to the above resources, classification criteria for architectural photoreproductions often focus on specific attributes that aid in their identification. One important criterion is the color of the lines in the image. In positive images, the line color corresponds to the intended design, while in negative images, the line appears white, though it is technically the color of the substrate (paper).

A summary of the interpretations of color as indicative of the used process, according to relevant literature [1,2,4,5] are presented in tables 1 and 2.

Table 1 Summary of the description used for background color of negative photoreproductions.

Blue	Cyanotype (blueprint); diazotype
Brown	Vandyke (dark brown)
Black	Silver gelatine contact print (Photostat)-(embedded in emulsion, black or silver); negative indirect electrostatic print (XEROX); negative direct electrostatic print (Electro-fax)

Table 2 Summary of the description used for line color of positive photoreproductions

Blue	Cyanotype (blueprint or pellet print); Diazotype (blue-black, green); Aniline print

	(blue-black); Hectograph (bright blue, lavender, green)
Black	Silver gelatine contact print (black-silver); Diazotype (black-grey, black-blue, black-brown); Gel-lithograph (DOREL, true-to-scale) (black, black-brown); Anthrakotype, Negrography (black), Electrophotography (black-grey); Lithography, Photolithography (black, black-brown or other)
Brown	Vandyke (yellow-brown); Ferrogallic print (black-brown); Diazotype (light brown); hectograph; Gel-lithograph; Salted paper-albumen print
Red	Aniline; diazotype; hectograph
Violet	Aniline; diazotype; hectograph

It should be noted that the description of the line color, as characterized only by observation, is highly subjective, therefore it cannot be used on its own. Because of the wide spectrum of colors, as well as how they are perceived by the human eye, there exist descriptions of colors that could be included in each category, such as purple and lavender for violet, or orange and pink for red. These descriptions are highly subjective, even in "pure" colors.

Objective

Proper identification of photographic versus photomechanical materials is essential for developing effective preventive conservation strategies for collections that include early 20th century photoreproductions. A systematic approach to their identification and classification would enhance our understanding of these materials and contribute to more effective conservation practices, ultimately prolonging their longevity [6,7].

This study aims to explore the possibilities offered by digital image processing and computational analysis to address the complex issue of the identification of architectural photoreproductions. An emphasis will be given to the distinction between the color of printed lines, as perceived by the human eye in relation to the classification obtained by computational analysis. The goal is to achieve a valid classification system for color interpretation, which is one of the main visual identification criteria for photoreproductions.

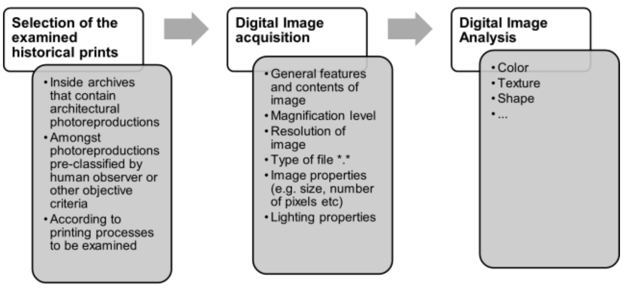


***Figure 1.** Steps of the general research methodology*

The steps of the proposed methodology follow a logical order of first acquiring the digital images from original archives, to proceed to computational analysis. The digital images can be analyzed, not only for color, but also for other attributes such as texture and shape. The process is described in Figure 1.

Methodology

Selection of examined historical prints

The first step was to research inside archives that contain architectural photoreproductions of the selected origin -Greece- and timeframe -first half of the 20th century. The examined prints are historic prints of known origin, date of creation and used process, belonging to a part of a construction company archive, currently stored in 'MONUMENTA' storage facilities.

As the scope is to train a classification system, it is more effective to use pre-classified prints. This can be achieved with the use of known classification criteria that are accurate, by using analytical techniques, contextual data or both. Also, the prints were selected to represent each process, and to have enough specimens that can provide us with statistically valid results.

They were divided according to their used process-color categories as follows:

1. Blueprints-negative: blue background, white line
2. Blueprints-positive: white background, blue line
3. Diazotype red: white background, red line
4. Diazotype black: white background, black line
5. Gel-lithograph (Dorel) black: white background, black line
6. Gel-lithograph (Dorel, Levidis) brown: white background, brown line
7. Aniline print multicolor: white background, red or blue line

In total, 30 prints were examined, from which the 11 more characteristic and suitable to the above categories were selected. All selected prints are on paper substrate, and they are all photoreproductions of architectural drawings, therefore they are primarily line drawings of approximately the same line width.

Image Acquisition

The aim of microscopical imaging is to retrieve the traces of the used printing process. The first step involves obtaining high-resolution digital images of historic prints. The images are taken under controlled lighting conditions to minimize environmental color distortions.

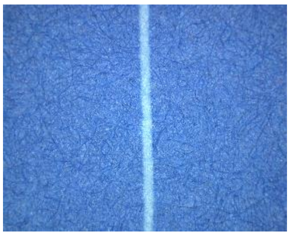
Table 3 Digital Image Properties

Main features	-Contains both lines and background -Lines are of similar width -Lines clearly defined from background -Negative or positive images
Level of magnification	-50 and 200 times (built-in system that has two focus points)
File properties	-*.bmp file -1280 X 1024 pixels - 24 bit
Image acquisition lighting standards	-Same lighting properties -built-in lighting system of 8 white light LEDs

For this study, the images were acquired with a digital microscope, under standard magnification rate and with the use of the internal lighting of the microscope. All microscopical images were taken using Dino-Lite AM4113T digital microscope, with a resolution of 1.3 megapixel in two different magnifications of X50 and X200 according to built-in system that has two focus points.

The chosen area for image acquisition contains both background and printed line. The line element is placed vertically to the center of the image obtained, to have a nearly uniform shape and distribution in all images.

All images used for this study were unprocessed. No color modification or noise reduction was used, to have the optimum results.



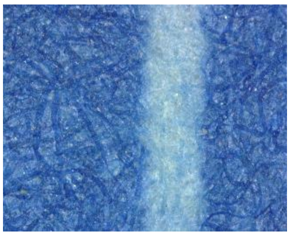


Figure 2. *Digital Images of blueprint negative in X50 magnification*

Figure 3. *The same area in X200 magnification*

Color Analysis

Computational visual analysis is a non-invasive technique that has previously been used for color analysis of printed inks [8]. In this study it was examined if a relationship in the use of the basic colors on the photoreproductions can exist and if this relationship can provide knowledge about the used process.

The blue color in cyanotype is known to be ferric-ferrocyanide (Prussian blue), while the colors for diazo prints consist of azo dyes that can result in a variety of hues. Aniline prints, which consist of aniline dyes can also have multiple colors on the same print. In the aniline prints examined, three different colors were present on the same print. The colors in gel-lithography consist of pigment inks, as Gel- lithography or 'Dorel' is the only one of the examined methods that is photomechanical. The two distinctive line colors that were examined (black and brown) are taken from two different types of 'Dorel' prints, the latter corresponding to the Greek printing company 'Levidis', according to the embedded stamp found on the print [7].

For the purposes of the study, RGB images are converted to HSV images, because the HSV color space separates the image intensity, from chroma or the color information, making easier the analysis of images that contain color [9], [10]. Additionally, the HSV (Hue, Saturation, Value) color space has a good correspondence to human color perception. Therefore, it is more suitable if we want to express human color appreciation and translate it to a computational value. The steps for the computational process are described in Figure 4.

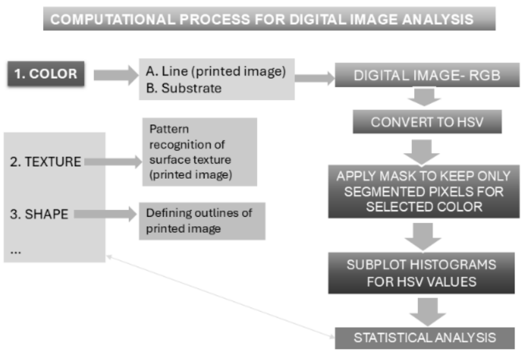


Figure 4. *Steps of the computational process for digital image analysis of color*

Color segmentation of microscopical images

The segmentation of images was based on different colors. During segmentation, the microscopical images were segmented into the colors that represent an area of interest. These colors are blue (cyanotype, aniline), red (aniline, diazo red), black (diazo black, dorel black), brown (dorel brown). A segmentation mask was created in MatLab as a binary image, where white represents the color (area of interest) and black the rest of the image (background) [11]. Figure 5 shows a typical example of the color segmentation of images while Figure 6 shows print images and their segmentation masks.

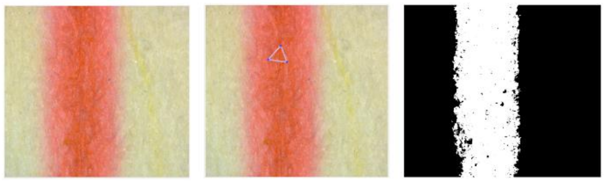


Figure 5. *Color segmentation of the mean value of the selected area- red color, aniline*

Some criteria were created in each selection for color segmentation:

-All colors should be on a paper support. The color segmentation mask chose the areas containing basic colors of the lines in positive photoreproductions and of the background on negative-blueprints.

-Each color was chosen to be segmented separately. The selected color areas contain only one color that does not overlap with another one.

-The color areas where the color reflectivity is not affected by the support reflectivity or is affected as little as possible was selected for color segmentation.

-The thickest areas of color with the greatest density were chosen, because, according to the Kubelka - Munk law, the color reflectivity of a layer is influenced as little as possible by the support reflectivity when the color layer is thicker [12],[13].

-Areas were chosen not to display local glazing.

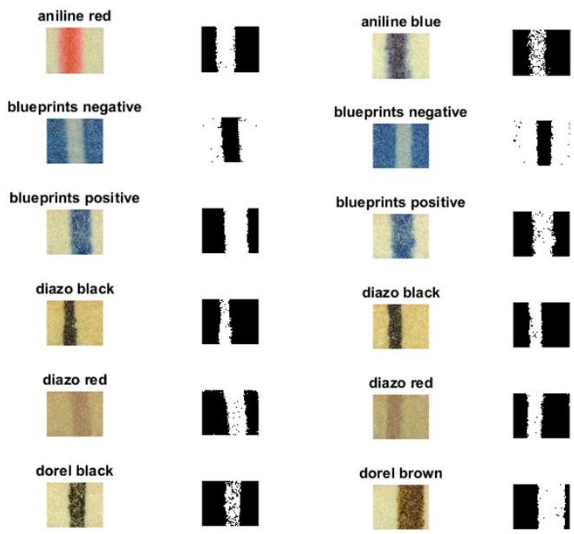


Figure 6. *Image segmentation of microscopic images in X200 magnification range, according to the printed- color area*

-Following acquisition and segmentation of the images, the magnification range of 200x was chosen as more suitable, because they contain more color information in each image. Segmentation also performed better, as the segmented areas were more accurately describing areas of color.

Measuring HSV values of the color lines

After the segmentation, the RGB images were transformed into the HSV system, measuring the hue, saturation and value. Taking into consideration these measurements of the HSV system, the respective histograms for each measurement of each color were created. The histograms correspond to the line colors observed on the prints, and pre-classified as such. A histogram of dominant colors can provide an overview of the image's color distribution, revealing peaks in certain wavelengths associated with different photoreproductive methods.

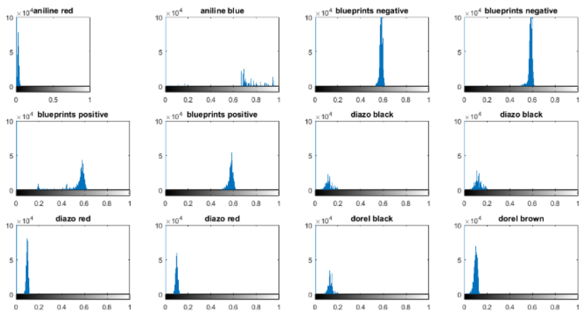


Figure 7. Histograms of hue values of print images

Figure 7 presents the histograms of Hue for different prints. The histogram of aniline red shows a real vivid red color. All blueprints are on the same hue area, although negative blueprints have a higher frequency of data points than positive blueprints. The blue color of aniline prints is on a different area that can be separated from blueprints. The red color of diazo prints is also clearly separated from aniline red. Interestingly; it has similar hue values to the brown Dorel. The black hues cannot be separated by their hues. They show very similar hue histograms either on diazo black or dorel black.

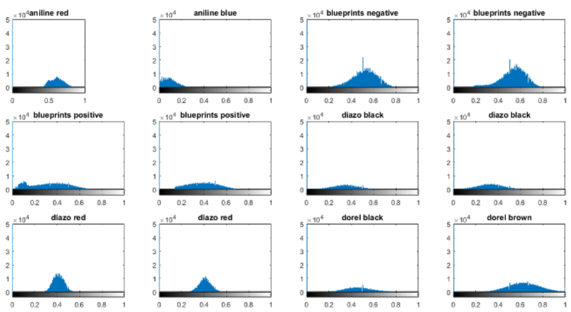


Figure 8. Histograms of saturation values of print images

Figure 8 shows histograms of saturation values of prints. All blue color prints (blueprint negative, blueprint positive and aniline blue) separate. Black color prints (diazo black and Dorel black) don't separate from each other, showing a wide distribution area. Dorel brown separates slightly from the black Dorel print. The two red colors of aniline and diazotype separate slightly.

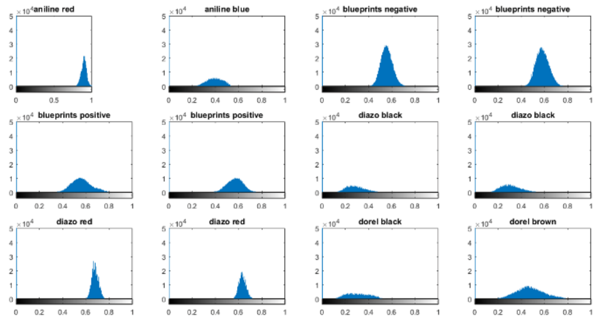


Figure 9. Histograms of values (intensity) of print images

Figure 9 shows histograms of values (intensity) of prints. Aniline blue from blueprints (negative and positive) separate. Reds from aniline and diazotype separate completely. Blackline prints do not separate, as they show low intensity values of a wider distribution. The brown Dorel shows a different image.

Results and Discussion

According to the histograms created, some observations can be obtained about the perceived colors and the colors analysed by computational analysis. The color described as 'blue' upon observation has very similar histograms of hue saturation and value, in the cases of blueprints- negative and blueprints-positive. Blue lines present in aniline prints show very different values. Therefore, the blue color created with the cyanotype process shows very different results to other hues that are also described as blue (or in relevant literature black-blue, lavender blue etc.)

Similar observations can be made on red color, present in the diazo and aniline lines. The red aniline color has a very high intensity and is a 'clearer' red than that of the diazotype red line. Diazo prints can have varied hues that could be a result of degradation or uneven processing, which might provide an explanation of the similar hues of black and red colors in diazotypes.

The black and brown colors are the most difficult to distinguish, even in human observation, which is something that we can expect when using HSV values.

Future studies

Future studies should be continued and directed in further directions:

-Computational models of prints should be created based on more prints. By expanding the dataset, more image samples from diverse historical sources will improve the accuracy and generalization of the classification system.Statistical models like k-means clustering or principal component analysis (PCA) can identify distinct color clusters in the image, which are then compared against known color signatures of historic processes.

-A next step would be the examination of whether the characteristics of the basic colors from other bands of the electromagnetic spectrum beyond the visible can provide additional information on the production techniques and materials of photoreproductions.

- Combining the color-based classification with other metadata (such as paper type, texture, or watermark) can provide an even more comprehensive method for identifying and categorizing historic prints.

Conclusions

The first of the conclusions is that although this is a preliminary study of historic photoreproductions, it shows that it can be used to find similarities and differences between photoreproductions with known and unknown color ranges. Thus, this proposed methodology shows that the combination of manufacture knowledge of prints and computational color analysis can allow us to approach the producing techniques of photoreproductions in the early 20th century.

Historic research can provide an explanation for the perceived colors, considering all the information, including the printing process, whether it is a photographic or photomechanical process, the chemical compositions etc. Color perception, either by human vision or computational analysis is employed to classify the subtle differences that is an indication of a certain chemical compound, ink or dye. Based on microscopic images, taken by a controlled protocol, we can distinguish basic colors that human perception classifies as similar, such as different ranges of blue color as observed in cyanotype and aniline prints, or red color, both present in diazotypes and aniline prints.

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Manto Sotiropoulou is a conservator of antiquities and works of art, based in Piraeus, Greece. She is a graduate of Conservation (2001, TEI of Athens), MA Conservation (2004, Camberwell College of Arts, University of Arts London) and MSc Protection of Monuments- materials and conservation (2020, National Technical University of Athens). Since 2023 she has been a PhD candidate at the University of West Attica and part-time tutor at the course 'Conservation of photographs and works of art on paper'. Her previous work experience includes several conservation projects led by the Hellenic Ministry of Culture, and more recently as an employee of MONUMENTA, on the project 'Documentation, conservation and digitization of Ergoliptiki archive'.

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