IMAGE ANALYSIS PIPELINE FOR CHARACTERIZING PHOTOLYTIC DEGRADATION IN DAGUERREOTYPES

Yuchuan Zhuang[1], Shuo Chen[1], Yuan Feng[1], Ralph Wiegandt[2], Robert Buckley[1] and Gaurav Sharma[1]
[1]Department of Electrical and Computer Engineering, University of Rochester,
[2]George Eastman House International Museum of Photograph and Film

ABSTRACT

We describe an image analysis pipeline for the minimally invasive analysis and characterization of light-induced degradation in daguerreotypes. To our knowledge, this is the first time that quantitative characterization and temporal analysis of the photolytic degradation has been described for daguerreotypes. We measure the impact of degradation using microscopic image capture before and after exposure of a small sacrificial region of the daguerreotype to light. The image analysis pipeline compensates for changes in capture position between the pre and post-exposure images and measures the effects of the degradation in the regions under test. Our results show that photolytic degradation follows a profile that is approximated as the sum of two exponentials with a time constants about 0.41 and 0.003 min^{-1}, with variation across regions.

Index Terms—*daguerreotypes, microscope, light source, image registration, SIFT, average intensity*

1. INTRODUCTION

The daguerreotype is a photographic image created on a halide vapor sensitized silver layer on a copper plate. The daguerreotype process was introduced to the world by Frenchman Louis-Jacques-Mandé Daguerre in 1839. By the early 1840’s the daguerreotype had become a commercial success throughout Europe and the United States. Daguerreotypes provide an invaluable visual record of people, places, and cultural iconography of those twenty years of early photography [1]. As these were the first years of human records of their visual world by light captured photographically, daguerreotypes are especially precious. Each daguerreotype is a unique direct positive image, and not until the mid-1860’s were they superseded by forms of emulsion photography and paper prints from negatives.

The nano-structured daguerreotype surface is highly sensitive to deterioration; environmental pollutants, airborne contaminants, effects of moisture, and photolytic degradation. The manifestation of these damaging agents is observable on all period daguerreotypes at varying levels. While chemical solution-based conservation treatments have been and are still being used to physically restore the image, current research reveals these treatments cause damage to the nano-structure that results in significant alteration and loss to the native high resolution image. These discredited methods pre-empt the full original image information to be extracted by today’s imaging technology, as well as what will be possible by future imaging technologies.

Environmental damage to daguerreotypes has been noted from the beginning –especially the damage induced by the sulfur compounds in 19th century, air from coal fires, locomotives and heavy industry. However, in very recent exhibitions of historically significant daguerreotypes, evidence of light induced degradation has been observed, which has raised significant concern from a conservation perspective [10]. There has, however, been little quantitative characterization of the photolytic degradation rates and spectral response parameters. Likewise, the fundamental physico-chemical explanations of the degradation pathways remain the subject of ongoing research. Because of the significant cultural and historical value of the daguerreotype, and the desire to view them, light-induced (photolytic) degradation has become a serious issue of for concern for the long-term preservation of daguerreotypes [13].

In this paper, we describe a microscope-based light exposure and image capture system and the associated image processing pipeline for the quantitative analysis of the photolytic degradation in daguerreotypes. A key property of the system is that it is assembled from commercial off-the-shelf and widely-available software components. With the system, it is possible to study the effects of different light sources, such as ultraviolet, tungsten and xenon, and different exposure durations. The optical path of the system can be configured so that the daguerreotype on the stage is either exposed to the light source under test or a light source for image capture by a camera mounted on the microscope. Details about the system and experiment procedure are described in [14].

2. MICROSCOPIC EXPOSURE AND IMAGING

To characterize the effect of light on daguerreotypes and any photolytic degradation, we conducted experiments using daguerreotypes from the study collection of the George Eastman House. Fig. 1 shows a schematic of the experiment. First, we selected regions of interest (ROI) on the daguerreotype for testing the effects of light exposure. The ROIs were small sacrificial areas with diameter of about 220 microns, typically located close to the edges of the daguerreotype plate. These locations allowed us to induce obvious changes while avoiding damage to the developed image located at the center of the daguerreotype. Next, we exposed the daguerreotype to the light source under different exposure times using the microscope illumination set-up. Then, we obtained images of ROI before and after exposure to measure the changes in the overall reflectance of the ROI as the way of quantifying the degradation. Light-induced changes typically darken the affected area of the daguerreotype, from which we can tell if ROIs are light sensitive. The reflectance of the exposed area was measured in both dark field and bright field illumination of the daguerreotype. Because changes in the position of the daguerreotype, which would lead to inaccurate result of degradation, are not completely avoidable during the experimental procedure, we use image registration to guarantee the images taken before and after the exposure are of the same region with no variation in position.

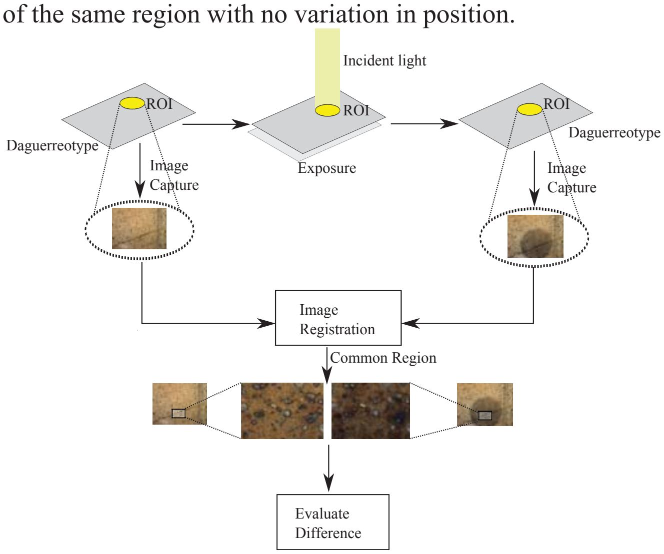


Fig. 1 Schematic of the experimental setup

By studying the average intensity change of the ROI on the daguerreotype under different exposure times, we can obtain the variation in reflectance with time. This variation in reflectance over provides a quantitative relationship between exposure time and the level of degradation, which we explored for different light sources, light intensity, and exposure times to develop a better understanding of photolytic degradation in daguerreotypes.

The facilities we used are as follows: a microscope mounted camera and a set of light sources with different spectral characteristics. The light sources used in the experiment are: Xenon, Tungsten, UV, and monochromatic light obtained via a monochromatic filter place before a Xenon light source. Our preliminary study indicated that the UV light source (having a total power density of 290 W/cm^2 distributed over the narrow region of wavelengths from 360 to 380 nm) caused the most severe degradation, so we used the UV lamp in our experiments. The microscope used in this experiment is Olympus BX 60 polarizing light microscope [4]. The spectrometer used in the experiment is Ocean Optics Jaz EL 350 spectrometer [2].

We conducted the experiment over six ROIs on two daguerreotypes. Five of these regions were exposed to a filtered UV light source while the sixth was exposed to a compensated UV light source. The locations of ROIs on the two daguerreotypes are shown in Fig. 2.

Fig. 2 Daguerreotypes used in the experiment

3. IMAGE REGISTRATION WITH SIFT

The images we captured before and after light exposure have small variations in position that need to be compensated for in order to obtain accurate estimates of the exposure induced changes. We therefore use the scale invariant feature transformation (SIFT) [11,15] to determine feature correspondences between the pre-exposure and post-exposure microscopic images, as illustrated in the example of Fig. 3, where a subset of the matching feature points are shown. SIFT is particularly well suited for the task because it focuses on the local structure in the images characterized by gradient orientation histograms, which is relatively insensitive to the changes in overall reflectance induced by the exposure.

The tentative feature correspondences obtained via SIFT feature matching are processed using the RANSAC algorithm [6] to eliminate outlier matches inconsistent with the imaging geometry and the resulting feature correspondences are then used to estimate the parameters of the homography [16] that enables registration of the images.

To test the accuracy of image registration and quantify its impact on the degradation estimates, we also performed a control experiment where we took two images of the same region after manually moving the daguerreotype slightly, without any exposure to our test UV illumination and registered and compared the images. In this control setting, we found that post-registration less than one percent variation in average light intensity was seen, which as we shall subsequently see is much smaller than the light induced variation, and therefore a very tolerable level of error.

For each test region we capture a group of images with increasing durations of exposure to the test UV illumination. After registering each of the images to the image captured prior to exposure, we can determine the average reflectance for the region as a function of exposure time. Analysis of the variation in the average reflectance allows us to characterize the temporal dynamics of the photolytic degradation.

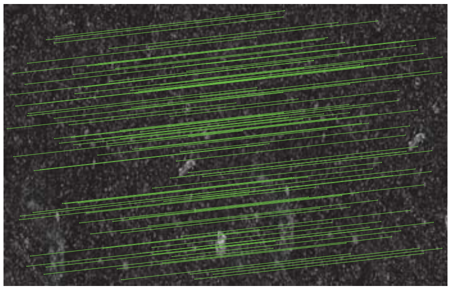
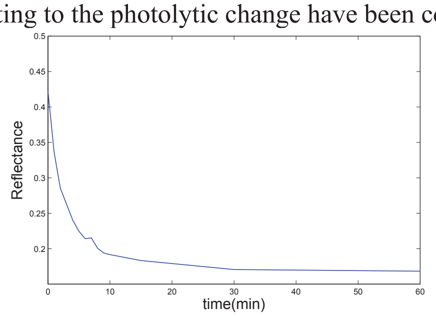


Fig. 3 SIFT matching feature points between two images of the same region taken before and after exposure

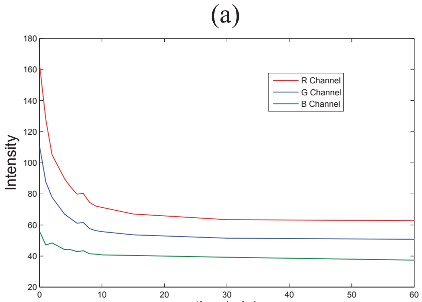
4. EXPERIMENTAL RESULTS

We calculated the average intensity of each region in bright and dark field before and after exposure at one-minute intervals over the first ten minutes and at 5 to 10 minutes intervals for the remaining 50 minutes of an hour-long exposure. For color images, we calculate average intensity in R, G and B channels, respectively.

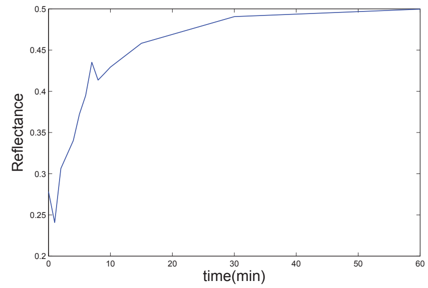
For bright field, the average intensity drops rapidly in the first 5 to 10 minutes and then decreases more gradually. We infer that under our UV illumination the daguerreotypes are degraded most significantly within the first 5~10 minutes and beyond that the phenomenon is much less significant because the light-sensitive materials contributing to the photolytic change have been consumed.



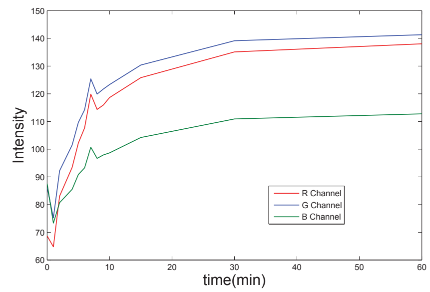
(a)



(b)



(c)



(d)

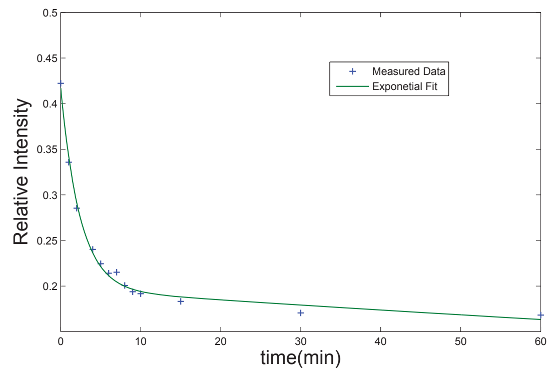
Fig. 4 Average intensity change in gray level (a, c) and RGB channel (b,d) of region 12 of daguerreotype 2 under UV light exposure. (a) and (b) are in bright field, and (c) and (d) are in dark field.

The results in Fig. 4 exhibit small spikes on the plotted cures in the first five minutes. These might due to fungal growth on the surface of daguerreotype, which are cleaned up in the initial light exposure, although their full nature remains to be explored.

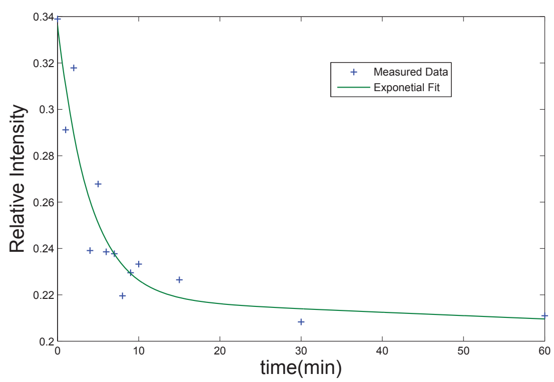
We find that an exponential curve of the form $a \cdot e^{-bt} + c \cdot e^{-dt}$ provides a reasonable fit to our observed light intensity over time, where for region 12, we find the amplitude coefficients a=0.221 and c=0.197 and the decay coefficients b=0.414 and d=0.003 per minute and for region14 these are a=0.118, c=0.2184, b=0.2524, d =0.001 per minute. Figure 5 shows a plot of the measured data against the exponential fit.

5. CONCLUSION

The image processing pipeline that we describe in this paper provides a minimally invasive technique to quantitatively analyze the effect of light exposure on daguerreotypes. Image processing plays a key role in enabling this analysis, in particular the SIFT+RANSAC based registration allows us to identify and compare the same areas before and after different periods of exposure despite the misregisration caused by inevitable sample movement during the imaging and exposure process. In our experiment, filtered UV light source has the most significant effect on the daguerreotypes compared with other light sources, such as the Tungsten lamp. The degradation of daguerreotype is dramatic in the first five to ten minutes while the change is more gradual beyond that time. The image processing methods applied here, and those used in our prior work [17], are relatively simple but enable novel applications in the conservation and digitization of daguerreotypes.



(a)



(b)

Fig. 5 Exponential Fit for BrightField data for Regions12 (a) and 14 (b)

We believe that this minimally invasive in-situ quantitative analysis provides a valuable technique for art conservators and researchers to characterize the photolytic response of a daguerreotype (or other materials) prior to exhibition. The development of a simple microscope based photometric and spectral response characterization platform, combined with the image analysis developed through this research, also provides a useful tool for conservation applications.

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