3—34 Computational Analysis for Conservation of Works of Art

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Abstract

Scholars in the areas of conservation of art are in need of scientific information that can be reliably used in the historical examination of works of art. Most existing methods for the analysis of the material used in works of art are based on destructive testing techniques that require the physical sampling of data. However, such methods cannot be used widely due to their destructive nature and the historical value of the artifacts. Non-destructive techniques such as reflectography are more suited to the study and conservation of works of art. Computer vision techniques can complement such diagnostic methods by computing models and interpreting the visual properties of the material used. The main objective of this work is the application of machine vision techniques for the non-destructive examination and conservation of works of art based on the modelling and analysis of the colouring present. In this paper we concentrate on the visual modelling of medieval inks used in scripting of manuscripts. Such models can then be used in the analysis and conservation of unknown writing inks found in manuscripts therefore eliminating the use of any destructive techniques.

1 Introduction

There is an enormous number of archived manuscripts worldwide. Many of these manuscripts cannot be accessed directly as they belong to very old and in most cases fragile collections. Inks are one of the main structural elements of manuscripts and their study can provide important information in the historical examination and conservation of manuscripts.

Until now our knowledge about the types of inks used in medieval manuscripts is sparse and it is mostly based on the examination of their composition of inks using destructive chemical analysis that require the physical sampling of the material. In most cases this is not desired because of the historical value of the artifacts. A computational visual-based approach provides a novel non-destructive method that allows reliable examination of historical artifacts without sampling. Recent reflectographical studies on the optical behaviours of the inks under visible and infrared radiation have shown that under experimental conditions, inks that have very similar photometric properties under visible light, can be separated when viewed under infrared radiation. This differentiation is mainly due to the different chemical composition of the inks [1, 2].

Based on historical information on the fabrication of inks we can divide them into the following categories:(a) carbon inks (b)iron-gall inks and their sub-categories and (c) mixed inks [3]. Table 1 shows analytically the chemical components of the inks.

Ink Types	*Chemical Components*					
	Carbon	$CuSO_4$	$FeSO_4$	Gallic Oxide	Alcohol	Arabic Oxide
Carbon	X					X
Metal-gall		X		X	X	X
Ink of Fourna		X		X		X
Iron gall			X	X		X
Mixed Ink	X	X		X		X
Type A		X		X	X	
Type B				X		X
Type C		X				X

Table 1. Chemical composition of inks.

In our previous experiments [2] which created the basis of our current work, we used old recipes to create 8 of the most common inks used in the Byzantine period. Following that we developed an experimental panel with eight squares, each containing a sample of one of these inks.

The panels were photographed individually under ultraviolet, visible and near-infrared light (360-950mm). Analysing the results we notice that although the inks demonstrated the same high degree of absorption under the ultraviolet light, there was a very distinct difference un-

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der the near infrared light [1]. Close analysis on the optical behaviours of the inks under visible and infrared radiation showed that inks that have very similar photometric properties under visible light, can be separated when viewed under infrared radiation.

The main objective of this work is the development of computational models that are able to characterise automatically the different types of inks found in medieval manuscripts. Such computational models can be used in the differentiation of the types of inks found on a manuscript and its classification. In addition to the more detailed and accurate analysis an image-based approach to the study of medieval manuscripts has the following advantages:

- The transportation of manuscripts to specialised laboratories is not required.
- It is not necessary to extract any ink samples from the manuscripts.
- Image-based techniques allow for the analysis of visible inks that are discoloured.
- Areas of interest for analysis on the manuscripts can be easily isolated.

In this paper we extend the work of Alexopoulou and Kokla [2] and show that a computational visual-based approach provides a novel non-destructive method that allows reliable examination of historical artifacts without sampling. This method is based on models of the photometric and reflectivity properties of the inks under infrared radiation and varying thickness values.

2 Ink Measurements

Based on the results reported in [2] we extended the experiments to include script samples. For our experiments we created two types of panels. One containing eight script samples and another containing eight squares made by the same ink as described in our previous publication.

The recording of the optical behaviour of the samples in the visible and near infrared radiation has been performed using a couple of tungsten photolamps, the 489 and 093 optical filters and a CCD infrared reflectograph sensitive up to 1200nm along with the image PRO-PLUS processing system. A standard black and white scale of 14 grey level tones has simultaneously been recorded in each reflectogram. This is shown in Figure 1. In this way it is easy to control the experimental conditions of the recording of the absorption of the ink samples as well as the acquisition parameters of the reflectograms set by the image acquisition software.

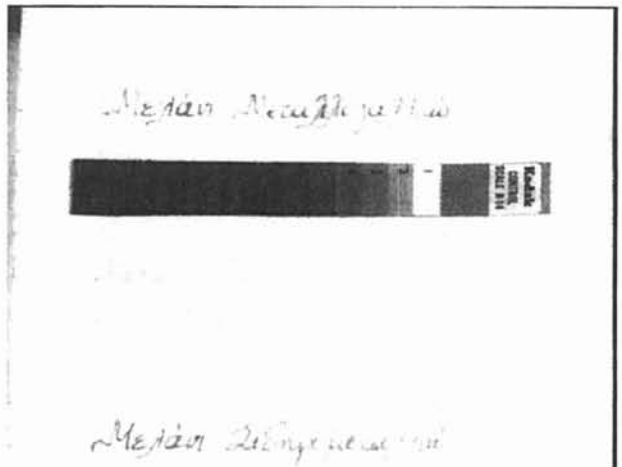

Figure 1. A sample script and the grey level scale.

The study of inks under scripting conditions, however, raises the question of isolating the reflectivity of areas where ink is present. "Non-ink" areas introduce noise, for example dirt, paper impurities, ink which has penetrated the paper from the back side of the page being tested etc. We have therefore developed morphological masks to isolate the areas of interest on the scripts.

The first observation we made was that the values measured for the scripts were not comparable or at least showing any significant relationship, whereas those of the squares could be easily linked to the inks. This can be easily explained if one considers the way the samples were created. When writing a piece of text using an ink pen the transparency of the ink means that the ink reflectivity is mixed with that of the paper. The squares on the other hand were "painted" and therefore the reflectivity of the paper is minimised.

To avoid the problem described above we created several script samples with different number of layers. Script samples of varying thickness were produced using one to ten layers of ink. Figures 2 and 3 show examples of script samples produced with one and ten layers of ink respectively.

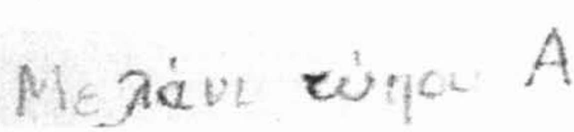

Figure 2. Script sample with one layer of ink.

From our experiments we noted that the results we obtain using 10 layers of inks in the script samples is similar to the results obtained with the "painted" squares. This is shown in Table 2, where a comparison between the two

[1] All images were adjusted to the same grey scale with the help of Image Pro Plus. With the aid of the same program we measured the absorption degrees for each ink

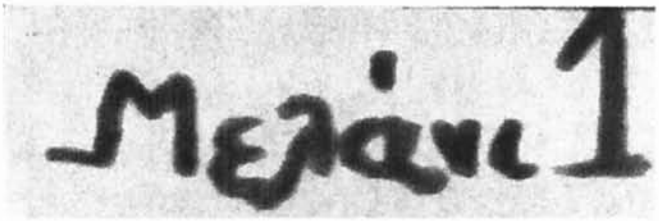

Figure 3. Script sample with ten layers of ink.

mean measurements is of the intensity of the inks under infrared radiation is made.

"Painted Squares	*Ten-layer Script*
0.6771	0.7015
0.4053	0.4182
0.6328	0.7591
0.4351	0.4531
0.5694	0.5873
0.367	0.367
0.8969	0.8995
0.6877	0.6961

Table 2. Comparison between the "painted" square and ten-layer script intensity measurements under infrared radiation.

3 Modelling Ink Colourings

Under normal scripting conditions and using non-transparent layers of ink, as the example shown in Figure 3, the photometric properties of each type of ink under infrared radiation can be modelled through characteristic intensity distribution curves. The intensity distribution of eight types of inks are shown in Figure 4.

In addition however, by examining how the intensity values of inks under infrared radiation vary with the thickness of the inks we can derive additional constraints. As inks are transparent, their reflective properties are influenced by the thickness of the liquid used and the reflective properties of the underlying support. In Figure 5 we show that the resulting measurements can form characteristic reflectivity models for each of the inks considered.

4 Observations and Future Work

Current experimental results show that by coupling information on the intensity distribution of non-transparent ink and the reflectivity lines of each ink we can derive visual-based computational models that allows classification of inks of unknown composition. Furthermore, we have also observed that there is a proportional difference in terms of reflectivity between the different layers. The more absorption radiation that an ink has under infrared

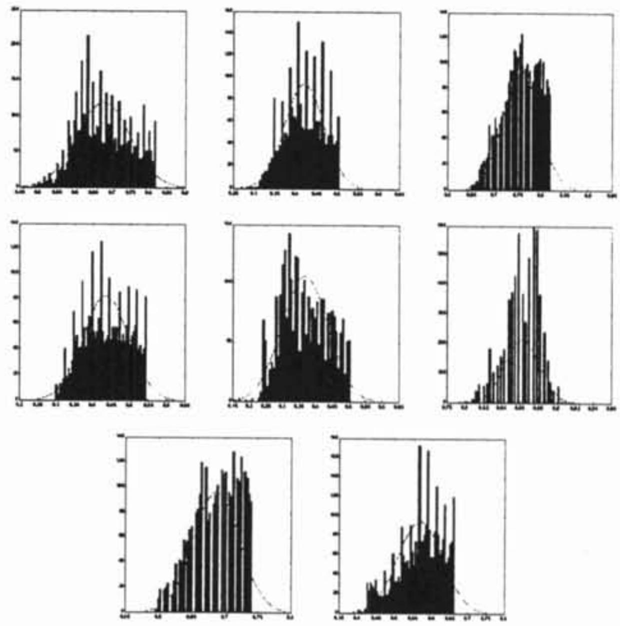

Figure 4. From left to right and top to bottom: Intensity distribution of (a) carbon ink (b) iron-gall ink and its sub-categories (c) mixed ink

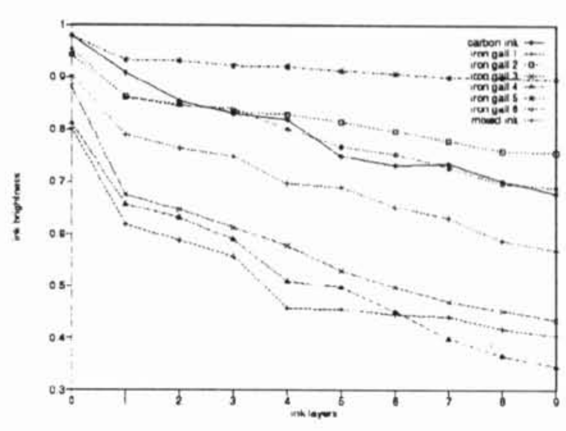

Figure 5. The intensity values of each ink under different thickness values form characteristic reflectivity lines.

light, the more the absorption degree changes as we increase the layers (irongall ink). On the other hand, inks which demonstrate small absorption degree under infrared radiation, have small range difference from the absorption degree of the small number of layers measurement to that of higher number layers (incomplete ink of type B). Moreover, the absorption degree of inks not containing metal salt is more than the absorption degree of inks containing gallic salt. Among metallographic inks, the ink of Fourna has the lowest absorption degree in all layers. This is shown in Figure 4.

Current work includes the identification of the type of ink from measurements in the visible monochrome and colour and infrared. This is based on constraints obtained from their chemical composition visible under infrared radiation as well as the intensity measurements in visible light.

5 Acknowledgment

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References

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