Towards the creation of generalised computational models for the characterisation of inks used in Byzantine manuscripts

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ABSTRACT

Many scholars researching manuscripts are interested in the characterisation of the type of inks found on such manuscripts as this adds vital information to the identification of the age and source of a manuscript. Our knowledge about the composition of the inks used in manuscripts is limited and even more importantly in order to analyse the composition of the inks we had to use destructive chemical analysis. In most cases this meant the extraction and analysis of actual samples from the original manuscript. With old and valuable collections even the use of very small samples is not a viable option as archivists and librarians will not allow any intentional destruction of the document, however small that it is.

An automated computer-based technique for the characterization of inks of unknown chemical composition, offers a desirable and non-destructive method that can be applied to most manuscripts. In this paper we present such a new method, which is based on advanced digital image processing techniques and results to an automated and non-destructive examination of manuscripts by providing visual analysis of ink samples.

Our techniques have been applied to inks found on Byzantine manuscripts. These inks were characterized through the creation of computation models using only visual information. The images used in our experiments were taken within the visible and near infrared spectrum.

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.

There are several techniques which enable us to identify date and place of the fabrication of the manuscripts. These techniques rely on some form of testing of the ink or the paper used. Traditionally though this testing involves sampling and laboratory analysis of the ink and paper of the manuscript. The method presented in this paper is completely non-destructive and is based on a computerised model of the visual properties of the composition of the inks under test.

Until now our knowledge about the types of inks used in medieval manuscripts is sparse and it is mostly based on the physical-chemical analysis of inks. Such methods however are destructive to the manuscripts and therefore their use is very limited if allowed at all.

Non-destructive techniques like reflectography as used in the conservation of art works can be applied also for the study of manuscripts. Advanced image processing techniques can complement such diagnostics methods by measuring the intensity of the reflected radiation and creating computational models of the visual information acquired. 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 present our results on the non-destructive identification of some types of inks used during the Byzantine period. In the remainder of this paper, first we give a summary on the types of inks used on Byzantine manuscripts and their characterisation based on their chemical composition. In Section 3 we describe our current experiments based on samples of script-panels before we conclude in Section 4.

2. BACKGROUND

Based on historical information on the fabrication of inks we can divide them to the following categories [Zerdoun 1983]:

- Carbon inks, which contain carbon, gum and solvent.

- Iron-gall(or metallogall) inks, which contain metallic salt (copper sulphate or ferric sulphate), galic oxide, gum and solvent. In this category are found the incomplete inks, which have composition similar to the iron gall inks but do not contain all of the ingredients of iron gall inks.

- Mixed inks which contain carbon, metallic salt, gallic oxide, gum and solvent

In our first experiments, which created the basis for 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 – 950nm). Analysing the results we noticed that although the inks demonstrated the same high degree of absorption under the ultraviolet light, there was a very distinct difference under the near-infrared light[1]. Closer 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. These results have been presented at the 6th International Conference on "Non-Destructive Testing and Microanalysis for Diagnostics and Conservation of Cultural and Environmental Heritage" [Alexopoulou et al 1999].

3. EXPERIMENTS ON SCRIPT SAMPLES

Based on the above results we have 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 inks as described in our previous publication (see figure 1 for sample scripts and table 1 for the ink composition)

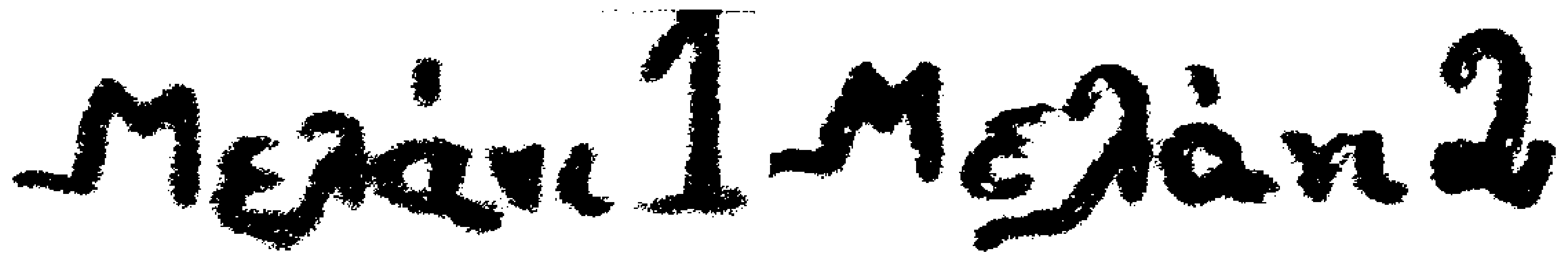

Figure 1: Two of the script samples (ink 1 and ink 2).

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 B+W 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 2. 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.

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[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.

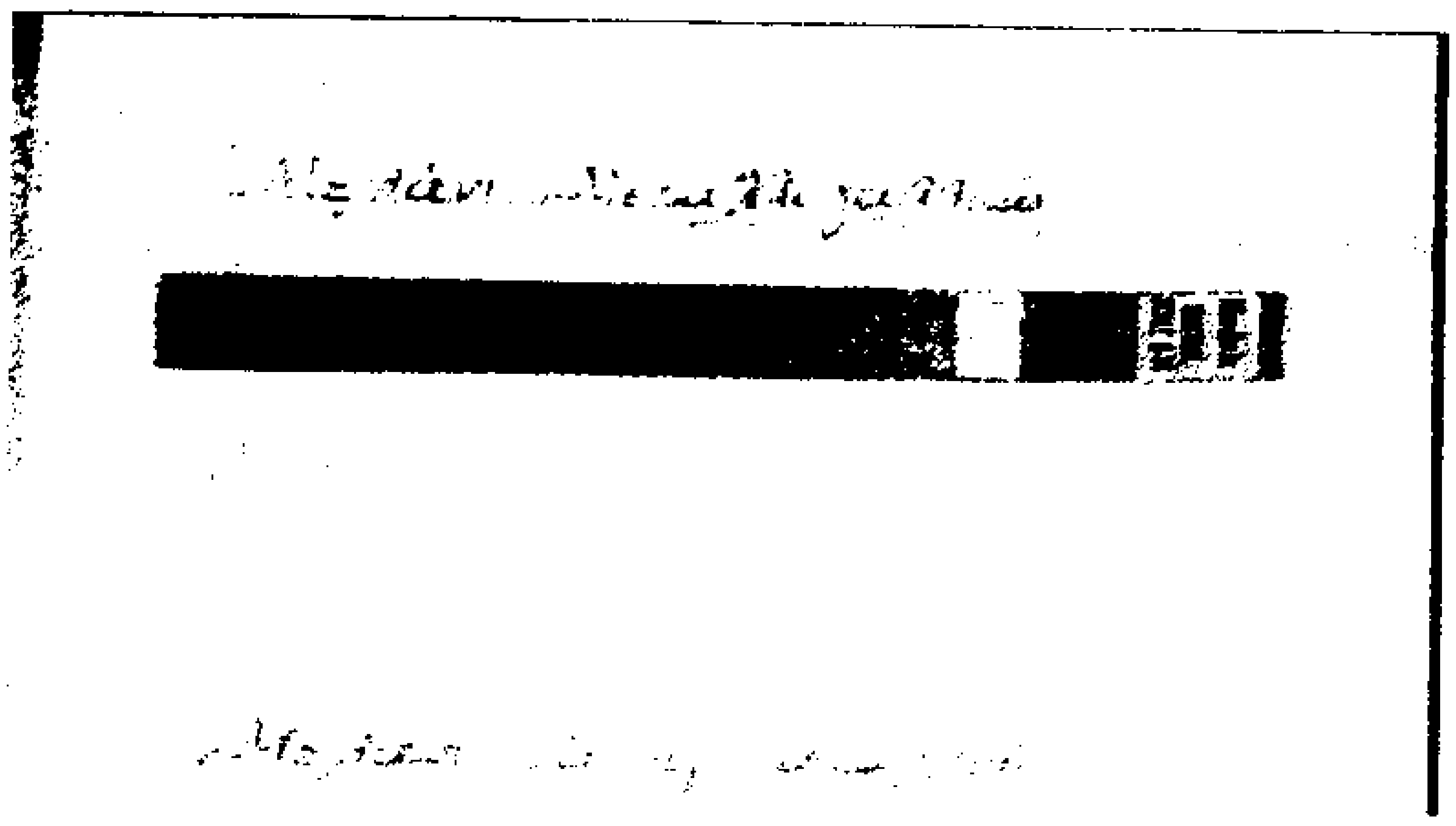

Figure 2: Photograph showing a sample script and the grey level scale

The study of inks under scripting conditions, however, raises the question of isolating the reflectivity of areas where ink is present. 'Non-ink' areas may introduce *noise* for example dirt, paper impurities, ink which has penetrated the paper from the back side of the page being tested etc. This noise distorts the readings and is extremely difficult to remove after the measurement has been taken. To overcome this problem we have developed a number of masks, which only permit the measurement of the reflectivity of the 'ink areas'.

A summary of the pre-processing applied to the images is as follows:

1) All photographs of scripts were taken together with a standard black and white scale (See Figure 2). By using the scale as reference we adjusted al images so that the results were as close to the same light and colour conditions as possible.

2) We also adjusted all images so that there were not differentiations of 'illumination' (light) at various parts of the image. Usually this occurs at the edges of an image and is almost always down to the positioning of the camera and the light source used.

3) We also removed areas where there was obvious distortion due to paper (i.e. paper decay) or noise introduced by other materials (dirt etc), which could influence the intensity of the measurement,

4) We removed (using a suitable mask) the non-ink areas.

We have also ensured that the ink samples were well separated so that there was no cross-interference.

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 for the squares could be easily linked to the inks (see table 3). This can be easily explained if one considers the way the samples were created. When writing a piece of text, especially using an ink pen it is very difficult to ensure uniformity of the ink throughout the text. This can be seen in the sample of Figure 3:

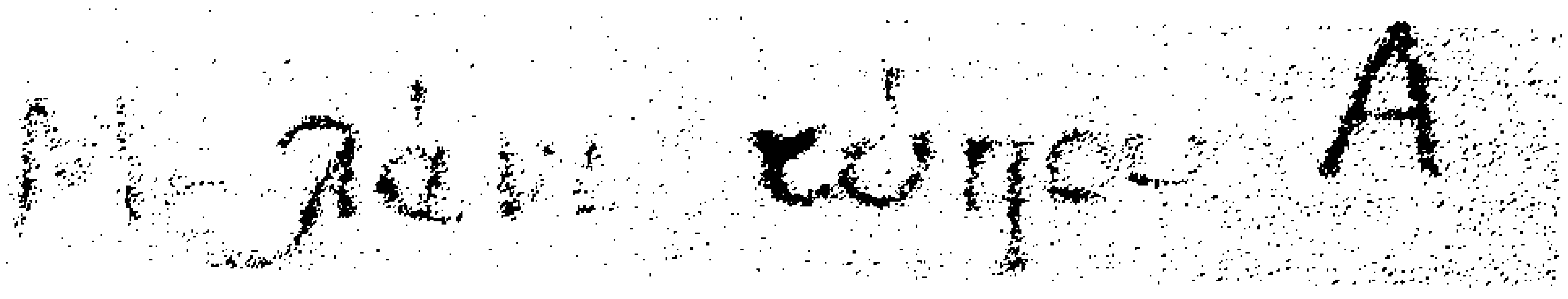

Figure 3. Typical hand script sample where the distribution of ink is not uniform.

In this case even though the ink is the same, the reflection generated by the above sample gives different values depending on the different areas of the image. Furthermore, the transparency of the ink in some areas means that the ink reflectivity was mixed with that of the paper.

The squares on the other hand, were more uniform as they are in fact painted rather than "written", and as such the distribution of the ink was more uniform. The values recorded using the squares are shown in Table 3.

To get similar results from the scripts and avoid the above we started creating the same script but with several layers of the ink (effectively overwriting the text several times). To identify the number of layers which could give us consistent results and similar to those of the corresponding squares we created samples of each script using up to 10 layers of ink. The different measurements for the overwritten scripts can be seen in table 2. The notation in that table is as follows: ink<INK_NUMBER><LAYER_LETTER>. For example ink2C indicates the measurement of the script for ink number 2 at the third layer of ink (2 overwrites).

By comparing the two tables it is obvious that in order to produce the same clear results as with the squares, we need to over-write the scripts nine times (ten layers of ink).

3.1 RESULTS – OBSERVATIONS

Based on the presented measurements, it is obvious that the reflectivity of inks in the near infrared area of spectrum enables us to categorise them and to identify their ingredients. However, as presented, it is possible to differentiate the tested inks based on images of squares of inks (i.e. when the concentration of ink is very high), but not (always) directly from script samples.

The latter is due to the fact that it is difficult to differentiate/characterize the inks from script samples as the natural ink transparency allows the measurement to be affected by the reflectivity of the paper itself.

To avoid this and reach the same results as with the 'squares', we had to increase the number of layers of ink applied to each script sample to 10. At that level of concentration we have also observed that the difference between the inks was more and more apparent (see table 2).

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 light, the more the absorption degree changes from the small number of layers sample as we increase the layers (irongall ink). On the other hand, inks, which demonstrate small absorption degree under infrared light, have small width 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 metal salt. Among metallogallic inks, the ink of Fourna has the lowest absorption degree in all layers. For a comparison of the intensity measurements of the different inks after 10 layers see figure 4.

4. CURRENT AND FUTURE WORK

In order to complete the above experiments we have developed and currently enhance, several image processing techniques and tools, which allow us to:

- Automatically enhance the images in order to make visible, ink areas that weren't visible (or were barely visible with the naked eye)
- Enhance the visible edges of ink scripts
- Create and apply masks that will allow us to measure the intensity of the "areas of interest" (ink-only areas).
- Perform a number of measurements (ink-only area intensity, statistical toolboxes etc)

Current work includes further enhancement of the intelligent pre-processing for the automatic extraction of the noise, especially the paper introduced noise (in order to improve results on the script images) and the use of higher resolution infrared images.

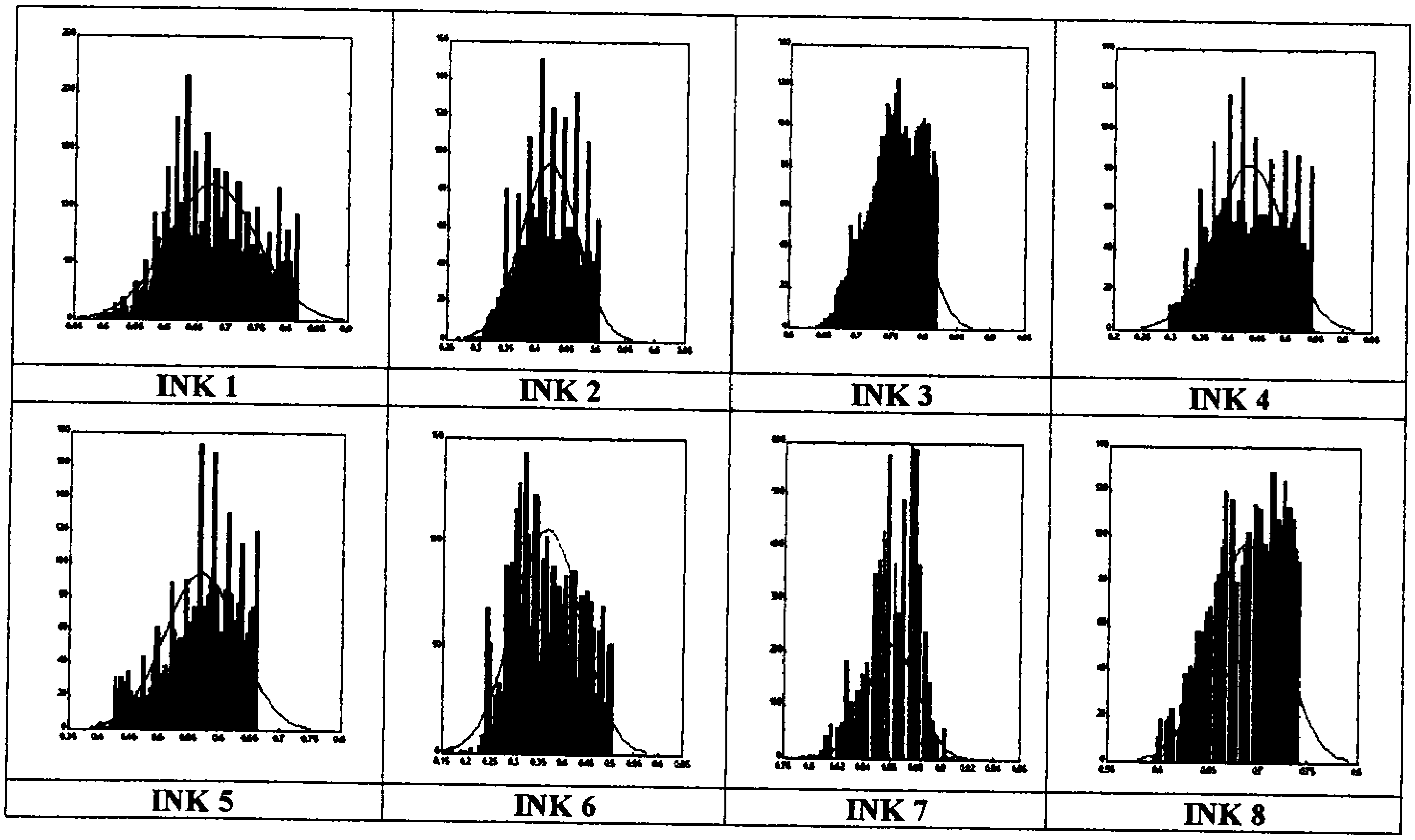
INK 1 INK 2 INK 3 INK 4
INK 5 INK 6 INK 7 INK 8

Figure 4: Intensity measurements under infrared light per layer of ink

TABLES

TABLE 1

INK KINDS	CHEMICAL COMPONENTS					
	Carbon	CuSO4	FeSO4	Gallic oxide	Alcohol	Arabic oxide
CARBON INK	x					x
METAL-GALL INK		x		x	x	x
INK OF FOURNA		x		x		x
IRON-GALL INK			x	x		x
MIXED INK	x	x		x		x
INK OF TYPE A		x		x	x	
INK OF TYPE B				x		x
INK OF TYPE C		x				x

TABLE 2
INTENSITY OF THE INKS PER LAYER

inklay1A	0.9786		inklay1D	0.8299		inklay1G	0.7308		inklay1K	0.6771
inklay2A	0.8021		inklay2D	0.5575		inklay2G	0.4455		inklay2K	0.4053
inklay3A	0.9413		inklay3D	0.8328		inklay3G	0.7965		inklay3K	0.7561
inklay4A	0.8812		inklay4D	0.6132		inklay4G	0.4973		inklay4K	0.4351
inklay5A	0.9027		inklay5D	0.7482		inklay5G	0.6513		inklay5K	0.5694
inklay6A.	0.8117		inklay6D	0.5895		inklay6G	0.4522		inklay6K	0.3458
inklay7A	0.9786		inklay7D	0.9215		inklay7G.	0.9069		inklay7K	0.8969
inklay8A	0.9535		inklay8D	0.839		inklay8G	0.7529		inklay8K	0.6877
inklay1B.	0.9083		inklay1E	0.8188		inklay1H	0.7341			
inklay2B	0.6184		inklay2E	0.4584		inklay2H	0.4414			
inklay3A	0.8624		inklay3E	0.8286		inklay3H	0.7783			
inklay4B	0.6746		inklay4E	0.5779		inklay4H	0.4707			
inklay5B	0.7893		inklay5E	0.6956		inklay5H	0.6306			

inklay6B	0.6563		inklay6E	0.5093		inklay6H	0.3992			
inklay7B	0.9321		inklay7E	0.9199		inklay7H	0.9006			
inklay8B	0.8609		inklay8E	0.8009		inklay8H	0.727			
inklay1C	0.8548		inklay1F	0.7485		inklay1J	0.7015			
inklay2C	0.5878		inklay2F	0.4563		inklay2J	0.4182			
inklay3C	0.8478		inklay3F	0.8148		inklay3J	0.7591			
inklay4C	0.6461		inklay4F	0.5293		inklay4J	0.4531			
inklay5C	0.7638		inklay5F	0.6885		inklay5J	0.5873			
inklay6C	0.631		inklay6F	0.4973		inklay6J	0.367			
inklay7C	0.9304		inklay7F	0.9122		inklay7J	0.8995			
inklay8C	0.8456		inklay8F	0.7669		inklay8J	0.6961			

TABLE 3

INTENSITY OF INKS AT THE 10th LAYER

Ink 1	0.6771
Ink 2	0.4053
Ink 3	0.6328
Ink 4	0.4351
Ink 5	0.5694
Ink 6	0.367
Ink 7	0.8969
Ink 8	0.6877

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