Analysis of ageing processes of paper graphics documents with different varnishes through hyperspectral imaging

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I. Introduction

Cultural heritage objects consist among others, in a wide variety of paper graphics such as maps [1], paintings imitations [2], etc. It is the work of conservators, to preserve these old samples in a good condition. One of the key factors is to preserve their original aspect as much as the conservation techniques allow to, still giving more importance to the preservation of the document against ageing processes. For this purpose, different varnishes are used to preserve these graphics [3,4]. However, still nowadays, these techniques are quite of a hand work, and there is no clear agreement on which varnishes should be used and in which concentration.

The most widely used varnishes for coating the paper documents are: shellac (SH) [5], Arabic gum (AG) [4], dammar (DM) [6], rosin (RS) [7] or egg white (EW) [8]. Besides, these varnishes can be used in different concentrations. When paper graphics coated with some of these varnishes are submitted to different ageing or alteration conditions, its aspect may vary depending on the severity of the process and the type and concentration of the coating.
Non-invasive techniques for the study of cultural heritage samples are of great importance in order to keep them unbroken. Among these techniques we can find Raman Spectroscopy [9] or spectral imaging [10].

II. METHODS

In this work we aim to characterize the changes in color induced by the ageing and alteration processes on samples coated with these five varnishes. Each of them has been put through 2 ageing processes: dry heat (DH) and climate chamber (CC), and 2 alteration processes such as: humidity (HM) and water immersion (WI). All of them were submitted in different time intervals (depending on the process), and with 5 different concentrations (0%, 25%, 50%, 75% and 100%), and compared with ground truth non-altered samples in the same concentrations.
We have used a hyperspectral line scanner system model Resonon PikaL, covering the visible and near infrared spectral ranges from roughly 383 nm to 1016 nm in a 4.1 nm interval (150 spectral bands in total). Since the samples were small enough, we could fit them in a linear scanning stage to simplify the capturing process.
CIEDE00 color differences have been calculated between altered and non-altered samples. Comparisons have always been made taking as reference samples of the same concentration.

III. RESULTS

Results show that, in all cases but RS, and for non-altered samples, the higher the varnish concentration the larger the color difference compared with non-coated samples (0% concentration).
In general, samples with low varnish concentrations do not change their color noticeably when compared to non-altered samples. In most cases, the ageing/alteration processes induce a higher color shift for higher concentrations. Somehow this is a price to pay for protecting the samples more robustly.
Also, for higher ageing time intervals, the color shift is higher specially in processes DH and CC. This is most noticeable in samples coated with RS.
Different trends are found in L*, a* and b* coordinates for the different ageing processes and varnishes. Individual cases are analyzed and the color shift is characterized for some of them. For AG, there is a trend towards becoming greener and yellower and lighter at the same time.
In figure1 we show the average CIEDE00 color differences across concentrations, found for all varnishes in the DH process.

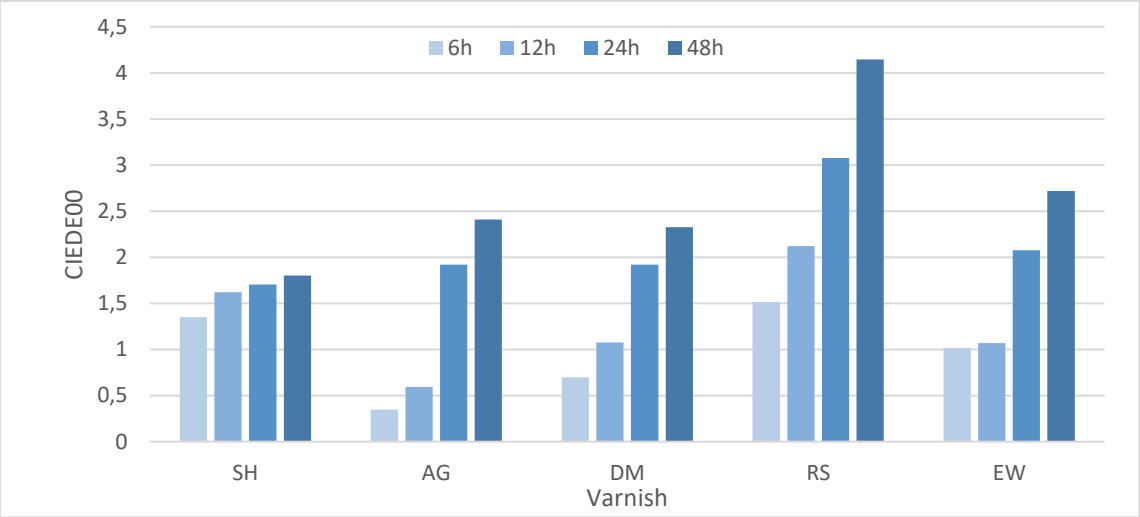

Fig. 1. Average CIEDE00 for DH ageing compared with non-aged samples.

There is a clear trend to increase color shift with ageing time. In particular, the most radical effect of ageing is found for RS, and the least noticeable change for SH.

Besides color characterization, it is our aim to model/predict the color shift of a new real sample and simulate its final aspect under any given illuminant after ageing, depending on the coating and concentration used. It is also important to describe the measured color changes with a language that is familiar to art and restoration professionals.

Figure 2 shows an example of two RGB rendered images from the hyperspectral reflectance image captured of the DH ageing process for varnish SH. Each row corresponds to a different time interval for the ageing and each column to a different concentration. On the left we see the simulation under A standard illuminant, and on the right under D65 standard illuminant.

Simulating the final color of the samples under different illuminants, makes it possible to study under which illumination the color shifts due to ageing processes are more or less noticeable, for each of the varnishes and concentrations.

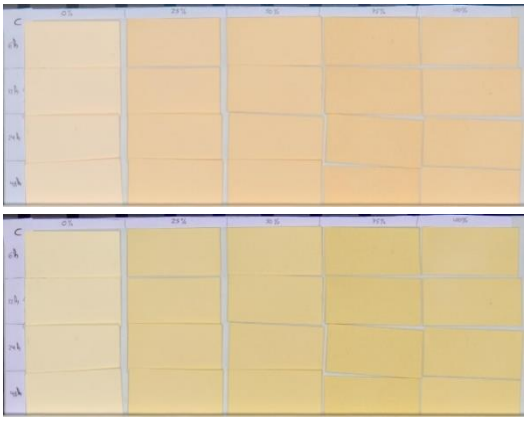

Fig. 2. RGB renderization from hyperspectral reflectance image under two different standard illuminants.

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