REMOVING THE ARTIFACTS FROM ARTWORK CROSS-SECTION IMAGES

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ABSTRACT

In this paper we propose a method for automatic removal of artifacts from artwork cross-section images. Cross-section images of minute samples are acquired during the painting material research of an artwork before actual conservation is performed. Such images are unfortunately damaged by the artifacts from grinding of the resin in which the sample is embedded. Removing those artifacts can improve the outcome of image segmentation and other image processing methods. The proposed algorithm can also simplify an analysis of underdrawings by reducing the canvas structure after infrared acquisition. Despite the idea is not entirely original, the application to cultural heritage data is novel and the implementation does not require user interaction.

Index Terms— Image processing, image enhancement, cultural heritage

1. INTRODUCTION

Today, the exploitation of digital image processing (DIP) approaches can be seen even in very distant areas such as art restoration applications. The ability to provide flexible analyzing tools and to improve quality and interpretability of input data obtained from processed artworks can make the DIP algorithms very useful and valuable for art conservators. Initially, DIP methods originally developed for other application areas such as medical research, industrial quality control, or remote sensing were applied. However, new approaches have been developed recently particularly for cultural heritage purposes, reflecting their special needs and aspects of processed artworks. One of the straightforward application of DIP methods is so called virtual restoration, aiming at the visualization of the original state of the artwork [1]. In addition, we can use achieved results for preliminary tests and suggestions, which restoration method would be the most appropriate [2]. The DIP methods can classify authors of the artwork [3] or even judge the genuineness of the studied painting [4]. There are many scientific papers dealing with individual tasks of artwork restoration, as well as complex systems, trying to offer unified solution (for example ArtShop [5]).

The main focus of our work lies in the application of DIP methods in materials research for art restoration/conservation and in the following report management and archiving [6]. Achieved results come from the fruitful cooperation between the Institute of Information Theory and Automation, Czech Academy of Sciences, ALMA, a joint workplace of the Academy of Fine Arts in Prague, the Institute of Inorganic Chemistry of the Academy of Sciences of the Czech Republic, and the Hamilton Kerr Institute, University of Cambridge, UK. Art conservators, materials scientists, and digital image processing researchers proposed and have been creating the system, which should reflect the demands of all participating sides.

Our paper presents recent achievement in the image data preprocessing in the developed system. In order to improve the quality of the data segmentation (dividing the image into meaningful segments) we have to deal with often low quality input images due to the data acquisition process and the sample preparation, respectively. We propose a method for automatic removal of the artifacts from artwork cross-section images of samples, acquired during the painting material research before actual conservation is performed. Section 2 introduces the overall system developed for the artwork restoration support, section 3 deals with the artifacts removal itself, section 4 describes experimental results, and, finally, section 5 concludes our paper.

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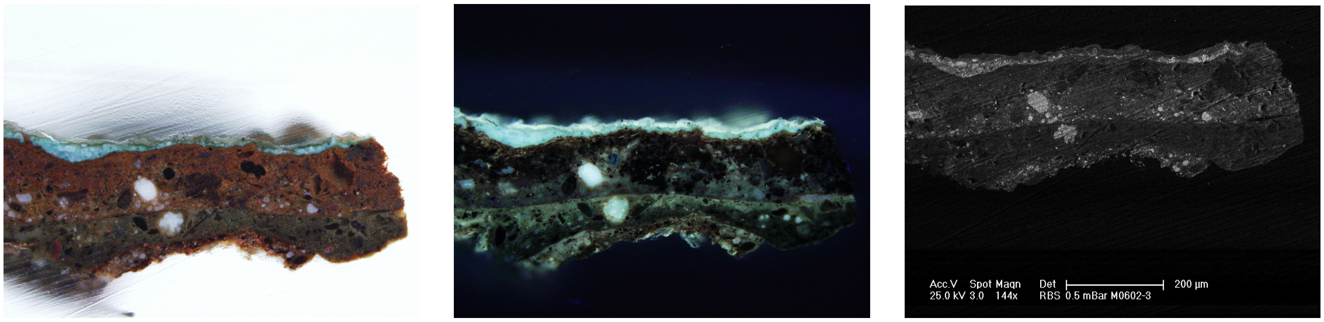


(a) VIS image (b) UV image (c) SEM image

Fig. 1. The images are acquired in three modalities - visible spectrum (VIS), ultraviolet spectrum (UV) and electron microscope (SEM)

2. SYSTEM NEPHELE AND IMAGE PROCESSING

Nephele is an extended database system developed to facilitate the work of art conservator. When some artwork is considered to be conserved, the painting material research report is assorted. The report describes the process of material research of given artwork. It contains all the acquired information about the object, e.g. general information about author and artwork, information about samples taken off of the artwork by an invasive method, results of chemical analyses etc. The database reflects the structure of report and can afterwards serve as a knowledge base for further research.

The report access is supported by means of a search engine. User can take advantage of two different approaches: traditional text-based retrieval and content-based image retrieval. The latter is enabled thanks to the image processing modules incorporated to the Nephele system, which handle the input image data acquired during the material research - microscopic images of minute surface samples. The samples are taken off of the selected areas of the artwork, embedded in a polyester resin, and grounded at a right angle to the surface plane to expose the painting layers. Due to grinding of the resin noisy artifacts form in the background. The images are acquired in several modalities. Stratigraphy (learning about painting layers) is usually studied in visible spectrum (VIS) and ultraviolet spectrum (UV) images, where the UV analysis makes use of the luminescence. Images from electron microscope (SEM) further extend the data set (see figure 1).

The multimodal input data have to be preprocessed before they can be used for image retrieval or material classification purposes. VIS, UV and SEM image triplets of the sample are often geometrically misaligned due to manipulation errors. SEM image has also different resolution. Therefore spatial alignment issue of the images has to be solved by image registration. Likewise, image segmentation is involved in preprocessing of the input data set. The noisy background encloses the cross-section and has to be removed. Also preliminary layer segmentation is performed. Unfortunately, present artifacts complicate these tasks and decrease the performance of the modules (see figure 4. The proposed method removes the artifacts and improves the outcome of image processing stage.

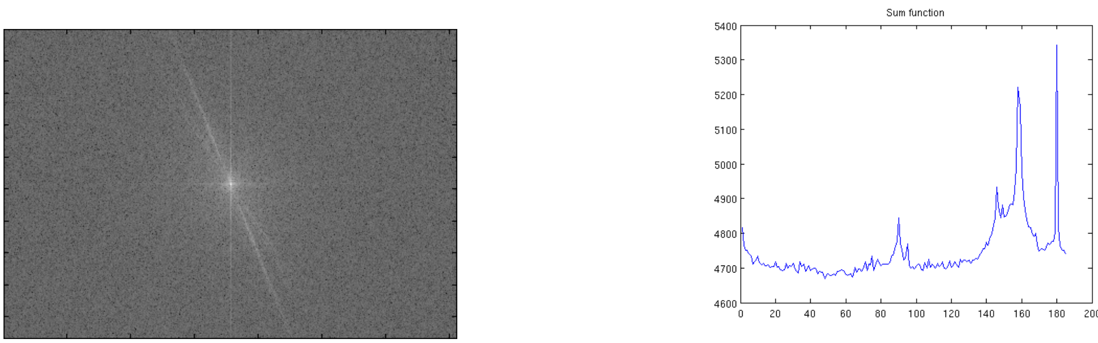
3. ARTIFACTS REMOVING

As stated before, the artifacts in the images originate from the grinding of the polyester resin, which is necessary to reveal the painting layers of the given sample. The proposed method can remove the artifacts completely or at least significantly diminished them.

Figure 1 shows the properties of the artifacts. They are omnipresent and in form of parallel lines. If we apply common Fourier transform to the grayscale input image, we can observe considerable amplitude response in a direction perpendicular to the original artifacts lines (see figure 2 (a)). In case of SEM images it is important to equalize the histogram first, which makes the lines more distinctive. Otherwise, the response would be weak. It is also better to remove the label from the image. Given the response, masking the Fourier spectrum and applying inverse Fourier transform provides demanded action to remove the artifacts in the image domain.

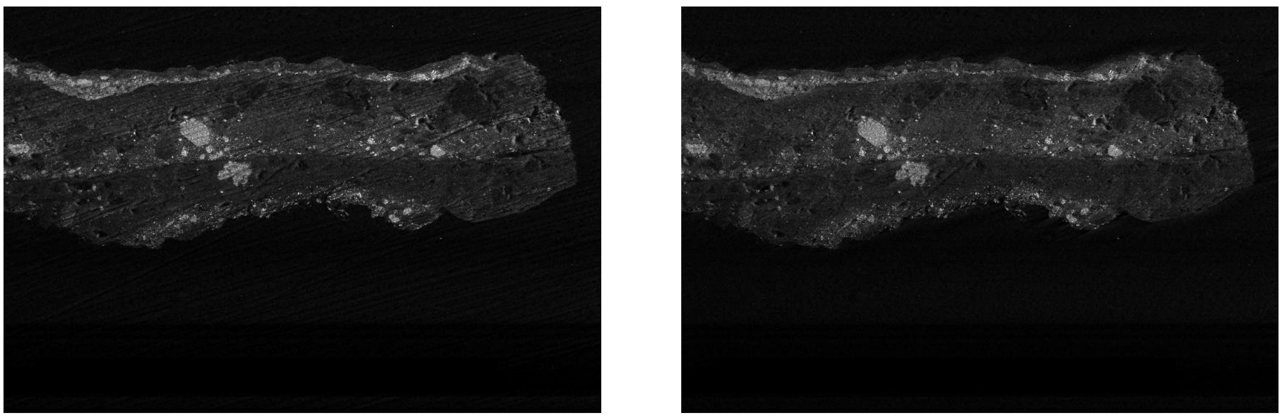
To achieve this, the function of column sums needs to be constructed. Fourier spectrum is rotated by one degree for all angles between zero and 180. In each step the values in columns are summed up and the maximum of the column sums is taken (with regard to the character of Fourier transform it is always in the middle). Thus, for each angle we have maximum response (see figure 2 (b)). Due to the properties of cross-section sample there is often strong response for angles 90 and 180. Other distinct peak determines the response of the artifacts, therefore its orientation. Sum function is smoothed to inhibit impact of distortions and peaks are found automatically (only the 3 highest peaks are considered).

Now we have enough information to make up binary mask, which will be used for removing the response from the Fourier spectrum. Afterwards, inverse Fourier transform is



(a) Fourier spectrum (b) Sum function

Fig. 2. Fourier spectrum of SEM image and sum function with several distinctive peaks



(a) SEM image before enhancement (b) SEM image after enhancement

Fig. 3. Example of an enhanced SEM image. Besides the improvement in the background, a texture of cross-section is adjusted.

applied to modified spectrum and enhanced result is acquired (see figure 3). Mask must be smoothed, otherwise the ringing effect is involved [7]. The parameters of the algorithm were tuned to have a minimal impact on the cross-section in terms of sharpness and level of detail.

4. EXPERIMENTS AND RESULTS

The images in the data set come from Academic Materials Research Laboratory of Painted Artworks (ALMA). It mainly consists of VIS and UV pairs, or VIS, UV and SEM triplets. Therefore, we have 76 VIS images, 62 UV images and 46 SEM images for testing purposes. The proposed algorithm was executed on each modality separately.

In case of VIS image data set, 71 images out of 76 were successfully enhanced (which means the artifacts were removed or significantly diminished). Concerning 5 dissatisfactory results, the response in Fourier spectrum was indistinctive or an appropriate peak was not correctly marked. Only 1 out of 46 SEM images was not processed in a satisfactory manner.

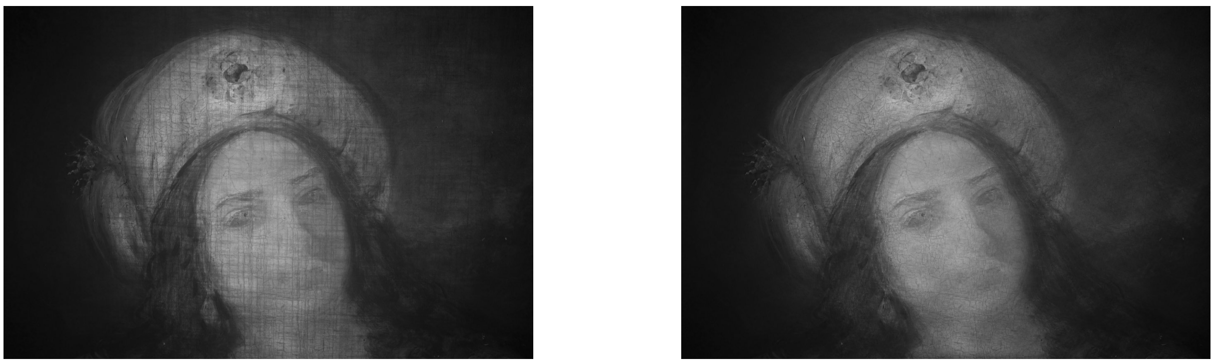
The algorithm performed poorly on UV data set. The responses in spectra were almost negligible. The background of the images is dark and the artifacts are nearly invisible, and thus they do not affect image segmentation and other image processing methods too much.

Figure 4 illustrates the influence of the grinding artifacts on outcome of specific image segmentation algorithm (Triangle, see [8]). The left image is the original SEM image with apparent artifacts in the background. Second image is binarized using the Triangle algorithms. Finally the right image shows the result of binarization applied to enhanced SEM image. The improvement of the algorithm performance is clear.

Also a different area of cultural heritage can exploit the performance of the proposed method, processing of infrared (IR) images of old paintings. The IR light enables to see hidden underdrawing, which capture the painter's original intentions. Unfortunately, IR backlighting captures also the canvas structure and its inhomogeneity. The algorithm helps to remove them and simplifies further analysis (see figure 5).

SEM image | Binarized SEM image | Binarized enhanced SEM image

Fig. 4. The background artifacts might influence the outcome of the segmentation algorithm.



(a) Original image | (b) Image after enhancement using the proposed algorithm

Fig. 5. Beside the underdrawings the IR backlighting shows also the canvas structure, which can be removed by the proposed method. The original underdrawing texture is well preserved. Thanks to Igor Fogaš, Moravian Gallery in Brno.

5. CONCLUSION

We proposed a method for automatic removal of the artifacts in cross-section images of given artwork. This improves the performance of following image processing modules such as image segmentation and image restoration. The algorithm was incorporated to Nephele system, which facilitates the work of material scientists and artwork conservators. It is fully automatic and stable.

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