A VISUALIZATION TOOL FOR COMPARING PAINTINGS AND THEIR UNDERDRAWINGS*

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Abstract – This paper will present a visualization tool for comparing images of paintings. The method starts with two types of images, one showing the color surface, the other the underdrawing - the first concept of a painting. The purpose of the tool is to support art historians in understanding differences and similarities of the preliminary sketches and the final painting. The algorithm consists of two consecutive steps. In the first step, the two images are registered with an affine transformation based on manually positioned control points. In the second step, the registered images are combined by replacing the value component of the color image – after conversion to the HSV color space – with the gray values of the infrared image. Several examples illustrate the steps and results of the method. Despite the simplicity of the algorithm, we can show the usefulness of the tool for art historians for identification, localization, and comparison.

INTRODUCTION

Interdisciplinary projects between computer-based imaging technologies and the field of art history have brought new aspects into both of the fields. While art historians benefit from new objective analysis methods and improved efficiency due to computer-based solutions, for technicians a new field of application was opened, which requires the adaptation and development of algorithms to the specific needs in art history [4].

Image processing methods are used for the corrections of distortions caused by the acquisition system, for stitching together detail images into a complete image (mosaicing), for improving the visual image quality by contrast enhancement methods or to restore the color of paintings. These visualization methods are already state of the art in museum imaging technology [1, 8, 2].

The goal of the method presented is to support the work of the art historian analyzing medieval altarpieces by comparing the painting surface and their underdrawings. The analysis is done primarily by visual inspection. The underdrawing - the first concept of a painting - shows the creative process of the artist and will bring understanding into the genesis of a painting from the artist's initial idea, preliminary sketches to the complexity of the final painting.

Normally the underdrawings are concealed by paint layers and must be revealed by near infrared methods. However in some paintings the paint may be thin enough for the drawn lines to show through directly. IR reflectography has become the primary tool for revealing underdrawings because many pigments used in the Middle Ages get transparent in the spectral range of 800 to 2400 nm. The reading and the interpretation of reflectograms is the key to understanding the role of the underdrawing in the creative process [8].

The most important point to bear in mind when analyzing the paintings is that we observe not only each image, that is the color image and IR image, in isolation but that we combine the two. The combination of both images brings two advantages. First, it will help to localize e.g. a certain stroke in the underdrawing to its corresponding position in the color image.

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Second, using this overlay technique the expert can easily see at one glance, difference and commonness. Comparison and interpretation of drawn and painted formations brings a clearer understanding in style and techniques of certain artists and insights into the practice of painting schools.

VISUALIZATION ALGORITHM

We now outline the method used to combine the images for visualization. We start with a color image and an infrared reflectogram (grey-scale image) of the same region of a painting. The algorithm consists of two processes, first the *registration* of the images, second the *combination* of the images.

Registration

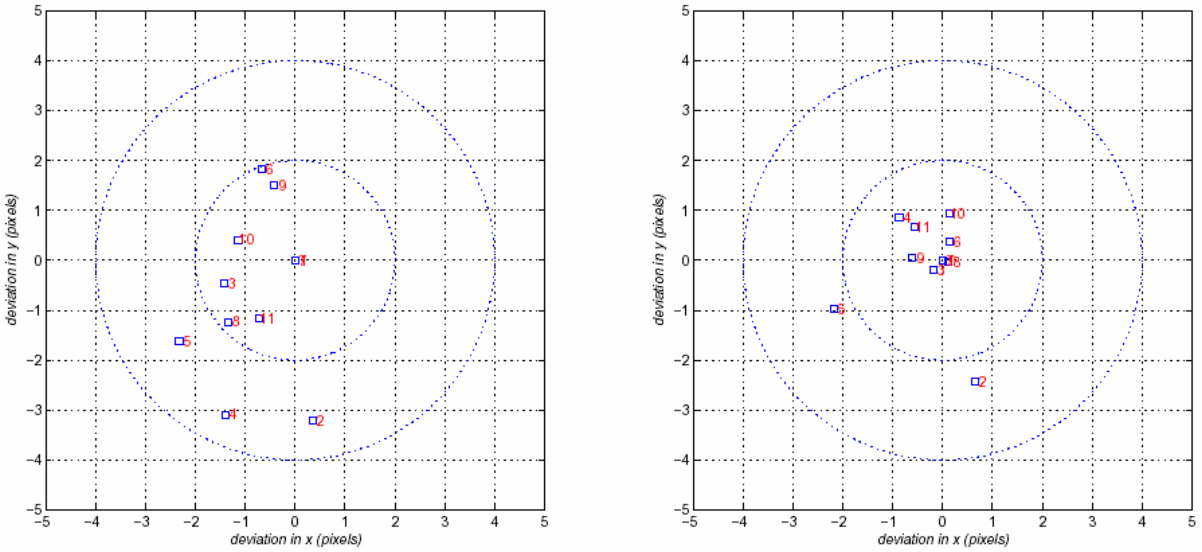
The images have been taken with a standard CCD camera that is sensible in the visual light spectrum and neighbored near infrared spectrum in the range between 400nm to 1100nm. To obtain a separate color and IR image a low pass and a high pass filter with the cutoff wavelength near 700nm have been mounted. Although we used only one device for the acquisition, the images do not match exactly. Thus, before combining or fusing the images in a way to improve information extraction, the images have to be registered. The registration process aligns one image to the other, by establishing a coordinate transformation that relates the pixel coordinates from one image to the other[6].

(a) (b) (c)

Figure 1: The color image (a) and the IR image (b) with control points and the combination of both images (c). (All color images are available on *http://www.prip.tuwien.ac.at/Casandra*.)

In our experiments we choose the color image as the image to be transformed (source image) and aligned with the IR image (target image). Figure 1(a) shows as example the color image and (b) the IR image of a detail from the *Wiener Neustädter Altar from the St. Stephans Cathedral in Vienna*. A linear polynomial distortion model also known as affine transformation which accommodates shift, scale, shearing, and rotation simultaneously is sufficient for our setup. The parameters of the model are calculated from two control points that have to be selected in a proper way on both images. In order to reduce extrapolation errors the distance between the points should be as distant as possible. The two control points in the color image and their counterparts in the IR image in Figure 1 are indicated by circles.

To test the quality of the registration, additional test control points are selected, transformed to the new location and the deviation between corresponding points is calculated. This measure is an indication for the quality of the accuracy of the registration. The red crosses in the IR image in Figure 1 denote the positions of the transformed control points.



(a) (b)

Figure 2: Deviation diagrams for the control points before (a) and after (b) adjustment.

The deviations between the control points of the target image and the control points from the source image after transformation are displayed in a xy-deviation diagram. Figure 2(a) shows the results obtained from the images and points depicted in Figure 1. All deviations are within the four pixel circle. Since the selection of the control points is done manually, we used the normalized cross-correlation to adjust each pair of control points within a local region. The improvement of the accuracy after this adjustment process can be seen in Figure 2(b). All but two deviations are within the two pixel circle.

COMBINATION

After the image registration, the color and infrared images are combined. This is done as follows:

1. Transformation of the color image from the RGB to the HSV color coordinate system.
2. Replacement of the V (value) image in the resulting coordinate system by the grayscale IR image.
3. Transformation back to the RGB coordinate system.

The HSV (hue, saturation and value) color coordinate system [7] is obtained from the RGB space by placing a new axis in the RGB space between the black and white points. This axis passes through all the grey levels, and is therefore referred to as the *achromatic axis*. The *hue* and *saturation* coordinates are then respectively the angle and magnitude in a polar coordinate system having the achromatic axis as z-axis. A generalized 3D-polar coordinate system incorporating the commonly used representations such as HLS and HSV as special cases is derived in [5], and could be used as an alternative to the HSV space. As the HSV space separates the luminance and color information to a certain extent, replacing the value image with another grayscale image does not affect the initial color very much.

As one is replacing one value image by another, one should be sure to use a representation in which the saturation is represented as a fraction of the maximum allowable saturation for a given value. This is in contrast to the 3D-polar coordinate representations which are recommended for image analysis applications [3]. As the latter are in the form of cones or double cones, there are some combinations of value and saturation which are outside of the valid color gamut. Such combinations could be produced by replacing one value image by another.

APPLICATION

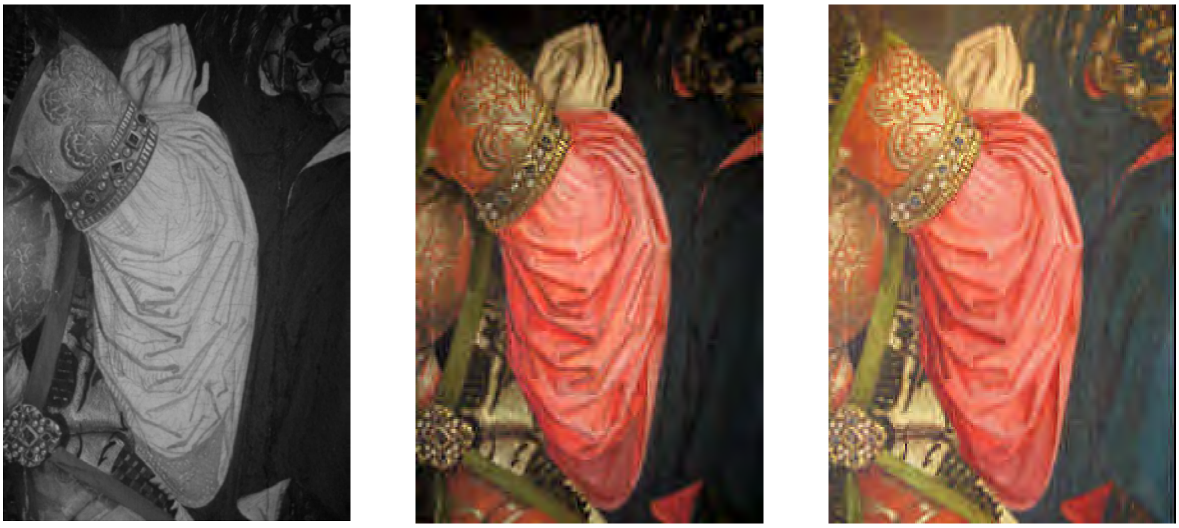
To discuss the results of the visualization we have selected a detail of the IR image in Figure 1. Figure 3(a) shows the IR image, (c) the color image, and (b) the registered and combination of the color and the IR image. Comparing the resulting color image (b) to the initial ones (a and c) allows the art historian to see more clearly which parts of the underdrawing are visible in the color image and which are not. In addition, the two color images allow the eye to easily detect corresponding regions between the images. For instance, the detail consists of a combination of long diagonal oriented lines and narrow vertical parallel strokes. In (a) these stroke formations appear very obviously, but are hardly recognizable in the color image (c). In the overlay image (b) the art historian can immediately see how the underdrawing acts as an aid for the execution of the length and depths of the folds in the final painting. He can prove how the strokes of the underdrawing are used as a guide for the execution of the final painting and how strictly the folds in the color layer coincide with the guiding strokes.

(a) (b) (c)

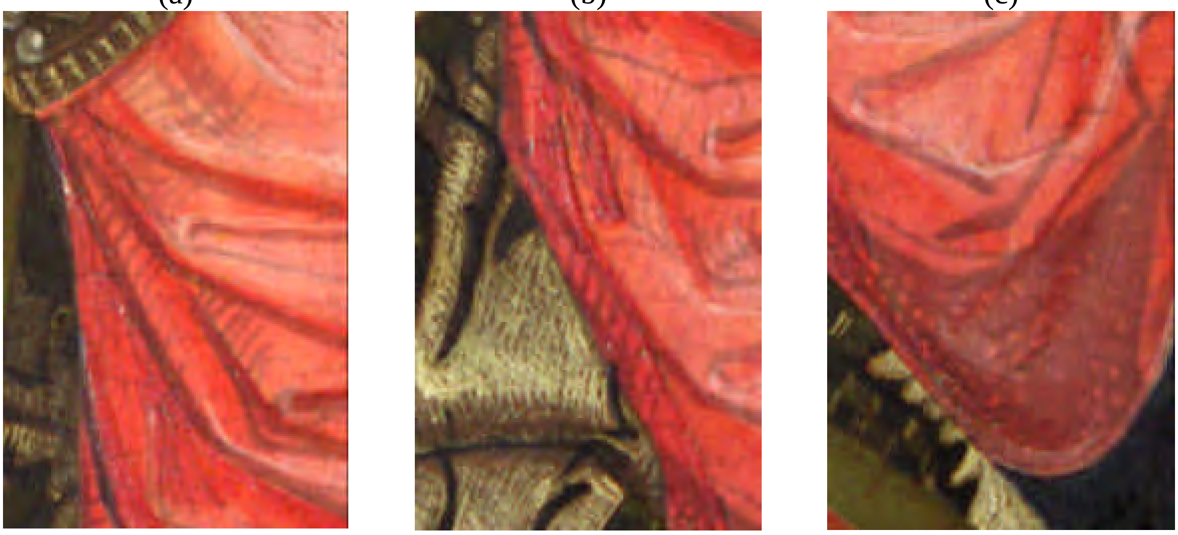
Figure 3: Detail from Figure 1. IR image (a), combined infrared and color image (b) and color image (c).

Figure 4 shows another example of the use of the visualization process on a detail of the *Meister des Wiener Schottenaltares* (about 1470, i.e. 30 years later than the previous example). The images (a-c) are arranged analogous to the previous figure. To better discuss the problems, we enlarged three parts of the overlay image (d-f). Deep folds in the material are indicated in the underdrawing by cross-hatchings. Examples can be seen in the upper part of (d) and in the lowest part of (f). Parts of the material which recede further into the painting are indicated by parallel lines, with the space between the lines indicating the rate of spatial recession (e).

Comparing the color images of both paintings, the cloth of the person depicted in Figure 1 and the sleeve of the person in Figure 4, the art historian notes more plasticity and twist in space. Again, these developments in the art of 15thC North European paintings are also indicated in the underdrawings. The comparison of the remaining wings of the altarpieces (respectively dating from 1447 and the 1470s) shows that – though there maybe differences in the final executions of the apprentices – the master's underdrawing guided the basic overall execution of the folds, plasticity, and depth in space. This technology irrefutably proves that the overall program of the master guided each step of the execution of these altars by the workshops.



(a) (b) (c)



(d) (e) (f)

Figure 4: The IR reflectogram (a), combined infrared and color image original color (b) and color image (c). Details from the combined image (b): (d)-(f))

CONCLUSION

This study has shown a method for producing an overlay of two images representing different content, but together can be used for provide crucial information to the art historian. Though this technology may seem rather simple from the technician's point of view, its use in art history has been unprecedented, and can be utilized as an invaluable tool for the art historian, particularly when several different surfaces are being examined.

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