Deutsche Gesellschaft für
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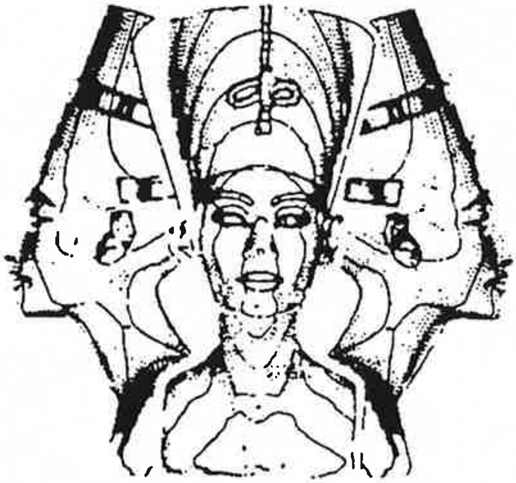
Berichtsband 45, Teil 1

BAM
Bundesanstalt für Materialforschung und -prüfung

SMB
Staatliche Museen zu Berlin Preußischer Kulturbesitz

AIPnD
Associazone Italiana Prove non Distruttive Monitoraggio Diagnostica

ICR
Istituto Centrale per il Restauro



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4. Internationale Konferenz Zerstörungsfreie Untersuchungen an Kunst- und Kulturgütern
4th International Conference on Non-Destructive Testing of Works of Art

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All good paintings crack: Nondestructive analysis of transport damage of paintings using digital image processing

Alle guten Gemälde bekommen Risse: Zerstörungsfreie Analyse von Transportschäden mittels digitaler Bildverarbeitung

Introduction

The increased pressure from art exhibitors to obtain masterworks for exhibitions around the world is a cause of great concern for conservators and conservation scientists. The ongoing controversy revolves around the undisputed possibility of damage to paintings during transport [1], and the obvious business and political interests involved with the lending of masterworks. Work to improve packing and transport conditions results in the paradox that the availability of art is facilitated, thereby increasing the number of paintings in transit and the risk to the paintings.

At the last Viterbo meeting the VASARI system (ESPRIT II No. 2649) for the acquisition of high resolution digital images of paintings was presented [2]. It was shown that transport damage to paintings can be detected with this system. In three recent publications, the basic concepts behind this work were described including technical details [3,4] and initial applications to paintings of E.-L. Kirchner and A. Sisley [5]. Briefly, high resolution digital images of a painting are taken with the VASARI system before and after transport. For most paintings, several sub-images are required to cover the entire painting surface. The before and after images are compared using digital image processing. Any change of condition between before and after is colour indicated (*indicator image*) and then interpreted, for example, as irreversible physical changes to the surface of the painting or simply dust particles. A *protocol image* is produced to assist in locating the positions of the indicated changes and to allow for a macroscopic interpretation of the area distribution of any changes.

This approach towards examining the surface condition of paintings has drawn the keen interest of conservators (as well as the corresponding disinterest of exhibitors) [6,7]. Further work has thus continued in this area with the aim of improving the image acquisition and data evaluation techniques. During this work, a number of paintings which have gone on exhibition have been examined digitally before and after transport. These are listed chronologically in Table 1. Each acquisition exposed various weaknesses of the system which are also listed with the corresponding painting in the table. The problems can be subdivided into experimental aspects, and other issues related to data analysis and interpretation. The purpose of this contribution is to examine the experience gained in these areas thus far, and to discuss solutions required for the optimization of the system.

EXPERIMENTAL ASPECTS

The problems with the acquisition of an image are associated either with the conditions in the room where the acquisition takes place (climate, lighting), the painting itself, or with the acquisition system (camera, data handling). These issues will be discussed separately below. It should be noted that these experimental parameters are dependent on each other.

(1) Climate: One of the major problems and criticisms of the current system is the control and stability of the climate in the VASARI laboratory where the paintings are imaged. No air conditioning unit is installed in the room. The climate in the room must therefore be controlled by carefully balancing the output of a standard humidifying unit and the ventilation system available in-house with the heat output of the instrumentation and external conditions defined by the building and the outside weather. A set of procedures has been specified which have been found to result in a fairly constant, reproducible humidity of about 53 +- 3 %. The reproducibility of the laboratory temperature is much more difficult, especially when a painting is first imaged in winter, goes on exhibition, and then returns in the summer. In winter, a reproducible temperature of 26 +- 1 °C during acquisition can be maintained. Summer temperatures, especially those attained in the recent heat wave (1994) in Europe can, however, already raise the background level of the laboratory to this level during the day. Acquisitions are therefore often limited to the early morning hours and must be performed fairly rapidly.

(2) Data acquisition system: To further reduce laboratory climate and heating effects, the time for obtaining an image has been significantly reduced since the VASARI system was first implemented. The use of a faster S-bus for data transfer and improved combing procedures for the raw data has speeded up the acquisition by a factor of 5.5. The acquisition and storage

time for one sub-image (3.000 x 2.300 pixels) has been reduced to 52 seconds. Even so, a larger painting such as the second Marc painting (Table 1) with about 120 sub-images takes about two hours to acquire, meaning that the climate must be maintained fairly constant for that period of time.

(3) Lighting and related problems: A further factor contributing indirectly to the time required for acquisition is the necessity for homogeneous lighting of the painting. Moreover, the lighting should be reproducible between the before and after images. This is not only a matter of the positioning of the light sources, in the present case two high powered slide projectors. The size and the physical state of the painting such as brightness of colours, surface roughness, supports, etc., also play a major role in the illumination of the painting and hence the quality of the acquired images and the time for imaging. Paintings with large variations in colour and brightness, and/or paintings with rough surfaces or reflecting materials (varnish, gold foil) pose particular lighting problems. In the former case, an average choice for the camera aperture and/or filters can result in a loss of information in very dark regions or overexposure of very light regions. Because of the low dynamics, the Memling painting, was, for example, imaged twice, once to obtain the details of the figure of John the Baptist himself as well as the background, and once to obtain the details of the much brighter lamb. This, of course, doubled the acquisition time.

Rough surfaces and shiny colours often produce reflections, which, even with careful reproduction of lighting conditions, can be different between before and after imaging. This often occurs for canvas paintings which are not only rough, but have slightly different canvas tension in the before and after state. These changes in tension result in different amounts of reflection. Each of these changes of reflection is indicated by the system. This increases the difficulty and amount of work required for interpretation. Polarized filtering provides some relief, but at the expense of brightness of the image.

Paintings should be acquired unframed if possible. Firstly the inevitable shadowing produced by the frame is avoided, and secondly, experience has shown that, at least for canvas paintings, most of the indicators occur along the edges of paintings where the most physical stress (shock loading, (re)framing) are to be expected.

(4) Camera: To improve the dynamics of the camera, the ProgRes 3000 camera used for the VASARI system has been upgraded from 7 to 8 bit.

However, this is not sufficient for dark paintings, and it is planned to replace this camera with a 12 bit MARC camera (ESPRIT III No. 6937) within the next year [8]. The ProgRes camera is also relatively temperature sensitive and is, therefore, cooled and stabilized by a fan, decreasing the slow shift of the grey values from more than 10% to 1% [9].

Data Analysis and Interpretation

After the painting has been digitally acquired, a software routine is used to compare the before and after images and produce the indicator images [3,9]. Two paintings by Brouwer and Ernst (italics in Table 1) are considered here to demonstrate the types of possible changes and the difficulties in the interpretation of the indicators. The results of the analysis of these paintings are summarized in Table 2 and on the protocol images in Figs. 1 and 2 respectively. The white squares in Fig. 1 and 2 mark 5 x 5 mm areas where colour indicators were detected. It should be noted that it is possible that a square contains more than one indicator. Where indicated areas are much larger, the square is located at the upper left hand corner of the area (e.g. Figs 3c and 4).

In Table 2, the total number of squares for each painting are given. It was found that these can be roughly divided into three groups: (1) indicators related to movement in the plane of the painting surface (crack opening/closure, crack elongation, particle movement, losses or flaking), (2) indicators related to movement perpendicular to the painting surface (defocussing related e.g. to blistering, lifting, changes in reflection), and (3) indicators related to dust or thread particles.

The indicators most critical to the surface condition of a painting are those related to actual physical changes in the surface of the painting. Examples of such changes are given in Fig. 3. These include loss or movement of paint in the plane of the surface of the painting and crack closure (Fig. 3a), movement of a single particle of paint within a crack (Fig. 3b), and slight unravelling of the canvas along the edge as well as crack closure (Fig. 3c).

The second group of indicators are those related to movements perpendicular to the surface of the painting (i.e. paint lifting, buckling, blistering, changes in support tension). Unfortunately, many good examples of indicators which clearly belong to the second group can only be shown in the original colour of the indicators themselves. For demonstrative purposes, one example can be seen in Fig. 4. This indicator image shows a large area whith a single crack. In the original colour indicator image it was found that there were differences in focussing conditions around such large cracks. This could indicate that the paint layer is starting to lift off of the surface.

The classification of a particular indicator into the first or second group has often proven to be difficult and the border between the two is still poorly defined. This is particularly evident when different lighting or focussing conditions occur between the before and after images (see Table 1). Changes in focussing can occur for canvas paintings due to slightly different canvas tension between the before and after images. Such changes can then, for example, make cracks artificially appear to open or close.

The last group of indicators is related to dust or threads such as seen on the Brouwer (Fig. 5). For the untrained eye, these can often be mistaken for cracks or particles of paint. For example, many of the dust particles observed appear as small white needles which (dis)appear between images or are slightly dislocated (Fig. 5a). Other particles can be identified through their typical thread-like shape (Fig. 5b).

Discussion and Perspectives

All good paintings crack: Although Sir J. Reynolds made this statement with respect to the sometimes unfortunate choice of his painting media, it applies also for art in transit, whether masterworks or works of art of lesser quality. With the improvements in the VASARI system made to date, it has been shown, that even under good transport conditions, which are the goal of this museum, the various types of microdamage mentioned could be detected in most of the applications to date (Table 1). It has been shown that improved condition monitoring is now possible.

One current and main concern continues to be the fact that even experienced conservators, who are familiar with the monitoring of art in transit, could have problems with the exact interpretation of the indicated microdamage. Normally, each monitored painting is optically examined to correlate the indicated damage with the visible condition of the painting surface as sensed by the conservator. This turned out to be difficult on the very brittle and delicate surface of the Ernst. The conservator observed, for example, that large areas of paint layer lifted slightly. Our analysis appears to have failed in some of those cases. Other indicated microchanges were not observed by the conservator in most cases because the actual damage was too small to find optically, or the area indicated could not be found.

We can, however, make some general observations concerning the macroscopic distribution of the indicators. As can be seen in Fig. 2, most of the squares on the Ernst are concentrated in certain areas, particularly along the edges of the painting. This could be related to the physical stresses on the edges and corners, seen by the painting during transport [1]. The indicators on the Brouwer (Fig. 1) are homogeneously distributed. This is to be expected, because only dust or thread particles were indicated on the panel. This could be confirmed under the stereo-microscope.

No real macrodamage such as wide-spread loss of paint or scratching was detected on any of the paintings listed in Table 1. An important question remains as to what types and size of microdamage could lead to macrodamage. It should be noted, that many paintings are on transit under much poorer conditions than those shipped and monitored by this institute. How much more macro- or microdamage are those unmonitored paintings suffering?

In addition to such fundamental research, further work is required before the VASARI system can be used routinely for the monitoring of transport damage. The main improvements still required include the following:

(1) improvement the user-computer interface (ease of operation of the system, menu driven operation),
(2) implementation of automatic or menu driven focussing (for example, to compensate any canvas movement),
(3) further improvement of the conditions during acquisition,
(4) semi-automatic detection and evaluation of changes before and after transport, and
(5) stereo imaging to enhance detection of changes out of the plane of the painting.

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Bibliography and Remarks

1 To clarify our terminology, transport includes any un- and reframing, (un)packing and out-of-house transport as well as in-house movements.

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Table 1

Paintings Analyzed or Acquired to Date

Artist	Painting (Provenance, Size)	Technical Problems	Indicated Changes
A. Sisley	The Road to Hampton Court (BStGS Inv.No. 13134; 39x55cm)	Poor focussing of before image, one sub-image lost	Crack elongation and -opening/ closure
E.-L. Kirchner	Boy Playing Cards (BStGS Inv.No. 13403; 70x62cm)	Lost data at the left edge	Deformation, new cracks, crack elongation, loss of paint
F. Marc	Picture with Cattle I (BStGS Inv.No. 10987; 92x131cm)	Lost data, light source lamp burned out, 330 min. acquisition time (110 sub-images)	Deformation, crack elongation
P. Cézanne	Still Life with Dresser (BStGS Inv.No. 8647; 73x92cm)	Overexposure of bright areas, 80h computing time	Many dust particles, deformation
A. Brouwer	Brawl between Peasants (BStGS Inv.No. 861; 30x25cm)	None	Dust
M. Ernst	Birds, Fish and Snake (BStGS Inv.No. 12260; 58x63cm)	Poor focussing of after image	Deformation, crack opening/ closure, loss of paint

Table 1 (continued)

Paintings Still in Transit Acquisition or Evaluation Under Work

Artist	Painting (Provenance, Size)	Technical Problems
H. Memling	John the Baptist (BStGS Inv.No. 652; 32x24cm)	Strong brightness variations, different lighting conditions between before and after imaging
F. Marc	Fighting Forms (BStGS Inv.No. 10972; 91x132cm)	None
E. Degas	Woman Ironing (BStGS Inv.No. 14310; 93x74cm)	Strong brightness variations; climate
E. Nolde	Flower Garden (BStGS Inv.No. L1716; 61x70cm)	None
E. Nolde	Wild Animals (BStGS Inv.No. 14514; 88x74cm)	Strong colour variations

Table 2

Indicated Changes

Type of Indicator	Brouwer[1]	Ernst[1]
Total number of indicators	17	70[3]
Actual physical changes in the plane of the painting	0	35
Movement perpendicular to the plane of the painting[2]	0	44
Of the above questionable but included	0	6
Dust particles	17	8

(1) More data concerning the Brouwer and the Ernst paintings are to be found in Table 1.

(2) Reflections are included in the group surface movements (see text).

(3) For the Ernst, the sum of the number of indicators in the three groups is greater than the total number of squares because a number of squares contain more than one of these three types of indicators.

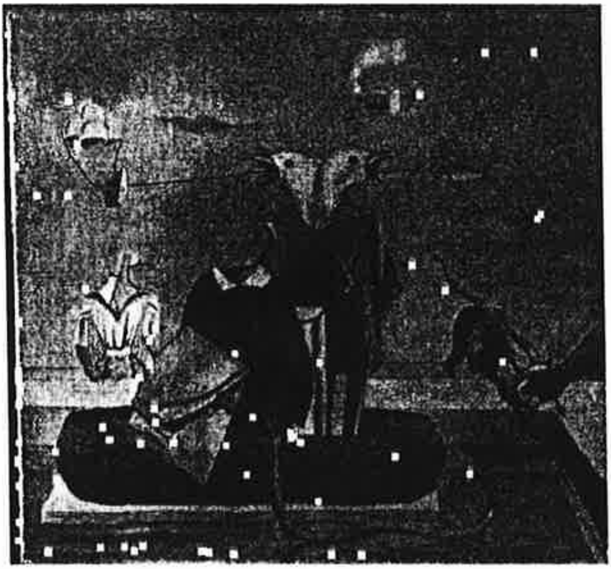

Figure 1 (top): Protocol image of the Brouwer.
Figure 2 (bottom): Protocol image of the Ernst.

Figure 3: Examples of actual physical changes within the plane of the Ernst painting.

a) Top row left: Indicator image (left), before (middle) and after (right) images

b) bottom row left: Indicator image (left), before (middle) and after (right) images

c) vertical right: Indicator image (top), before (middle) and after (bottom) images

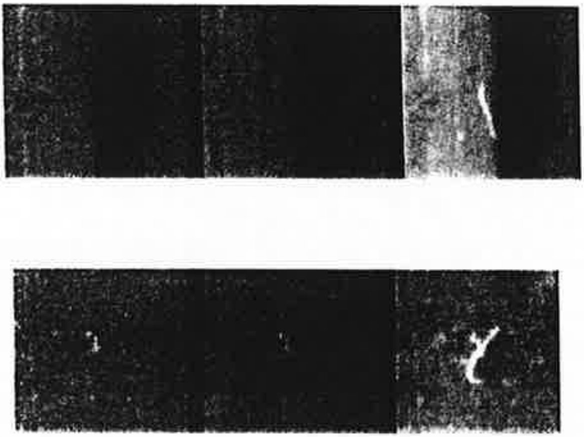

Figure 4: Indicator image showing surface movement perpendicular to the plane of the Ernst painting.

Figure 5: Examples of dust (top) and thread (bottom) indicators on the Brouwer painting (indicator image (left), before (middle) and after (right) images).