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Registration of transportation damages using a high resolution CCD camera

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ABSTRACT

This paper proposes a new approach to monitor the condition of a painting.That is the acquisition of the surface structure of the painting. As transportation damages are known to affect the crack pattern, very detailed images (cracks < 0.1mm) are required. A compromise between this requirement and today's feasibility consists in using resolutions of about 20 pixel/mm with 8bit, meaning images of 20k x 20k for a painting of 1m x 1m. A Kontron ProgRes 3000 on a high precision 3D motorized frame (repositioning accuracy < 0.01mm) is used for the acquisitions before and after transportation. Each pair of images is resampled to compensate for geometrical distortions. The crack network is then detected by using line detection algorithms derived from mathematical morphology. The images are finally superimposed and changes can be detected manually or automatically. While the main focus of this contribution is spent on technical details, case studies are used to discuss recent applications.

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1. INTRODUCTION

The growing number of exhibitions involves ever more transportation of important and valuable paintings all over the world. Therefore the importance of surveying these transports and monitoring changes is evident. It is well known that paintings suffer from transportation where they are exposed to mechanical stress and climate changes. There are various opinions on judging the risks caused by transportations: on one hand people would like to restrain from lending the objects in general, whereas others think that "modern shipping techniques and equipment can now virtually guarantee a safe journey of art works"[1].

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Most effort to improve the quality of the transportations is spent on optimising the transport, the packing method, the packing cases and climate and vibration control. However, very little research is done on measuring the transportation damage i.e. comparing the state of the object before and after such an event. Wennberg[2,3] compared paintings by photographing them before and after a real transportation. Baribeau et al[4,5] simulated a transportation by using a vibrating table and then representing the painting's surface by using their laser scanner. The above described works face problems caused by the limitation of the surveying to preselected details of the paintings and by an identification of the changes which is done by visual inspection only. Our approach tries to aquire the entire painting using a high resolution CCD-camera and a subsequent image processing chain[6].

2. THE HARDWARE

During the VASARI project (ESPRIT II no. 2649) a sophisticated acquisition system was built. The VASARI system (Fig.1) is composed of the following components:

- A positioning unit which moves a camera in a plane parallel to the painting. The possible travel of the camera is 150 cm in each direction. The distance between the camera and the painting can be up to 180 cm. All three axes are motorized (stepper motors) and driven by screw spindles. The repositioning accuracy is better than 0.01 mm in each direction.
- A high resolution CCD-camera (Kontron ProgRes 3000 with 3000x2300 pixels and 8bit).
- The painting is fixed on an integrated easel and is not moved during the recording, in order to minimise the risk of damaging a painting during the acquisition.
- The entire painting is illuminated by filtered light sources.
- The acquisition system is computer controlled. We use workstations (SUN SparcStation 2, operating system SUN OS 4.1.1, OpenWindows 3) to pilot the mechanics, to record the information and finally to process the data.
- A complete range of image processing software written in C is used to analyse the data.

3. THE SOFTWARE

As most paintings show surface defects appearing as small cracks we try to analyse these on the basis that the crack pattern is most likely to change during a transportation. The width of these cracks can be of 0.1 mm and even less. When working at resolutions of about 20 pixels/mm we are able to detect most of the cracks necessary for later analysis. In order to reach this resolution, the object has to be imaged in many single steps. This is achieved by moving the camera in a tile-like pattern so that each single image slightly overlaps with its neighbours. This set of images is then combined to give the total image. Because black and white images require markedly less acquisition time, information as to colour is dispensed with for the preservation of the object. This does not in any way reduce the quality of the representation of the surface topography and, in addition, reduces the amount of storage space and processing time required.

3.1. The pre-processing

The pre-processing of the digital images is done by classical contrast enhancement routines such as scaling and histogram equalisation. For future applications when acquiring colour images the suppression of coloured regions will be useful to improve the quality of the crack detection as most of the cracks should appear in grey. Thus, coloured pixels above a certain threshold will be suppressed in a pre-processing stage.

3.2. The detection of cracks

In general, the crack pattern is very irregular. In special applications the detection of regular patterns can be of interest. In this case special filter kernels are of use [7]. The following two algorithms are applied successfully:

- the algorithm of Vanderbrug[8] which was originally developed for road detection in satellite images.
- the top hat operator[9] derived from mathematical morphology and based on dilation and erosion of grey level images. This operator allows to modify easily the size of the detail to be detected as well as the contrast between the detail and the background.

3.3. The post-processing

The suppression of noise as well as the reconstruction of discontinuities can be envisaged but are not used too much at the moment because of the danger of creating other artefacts affecting the comparison of the images. Great care is taken in order to avoid misinterpretations.

3.4. The resampling

As the paintings have been hung in an exhibition between the two acquisitions it is impossible to fix them in exactly the same position as before. Other difficulties are encountered as the paintings are not rigid at all. Therefore a resampling of the images taken after the event is a very important step in our process which is treated here separately from the other image processing steps. Depending on the quality of the acquisitions, we use first or second order resampling techniques. First order resampling is sufficient when carefully placing the painting on the easel and changing nothing on the mechanics. In other cases second order resampling has to be applied e.g. when the mechanical system had been modified. Whereas manual resampling methods could be used, we prefer the use of automatic routines. In order to produce satisfying results a first resampling is necessary for a rough correction of the translations. To avoid errors and to keep computing time down this first resampling step is applied to shrunken images just as is done for satellite images[10,11]. The procedure now extracts pairs of patches of the two high resolution images to be compared. The displacement for each pair of these patches is analysed by the use of correlation algorithms. This is the reason why the above described resampling step is necessary. Otherwise correlation procedures will fail or, if not, they will be very time consuming. In our case the size of the patches is set to 50x50 pixels in order to allow precise comparison of these patches. The distance between the patches varies according to the x- and y-size of the image. Now the middle of a patch is defined as an artificial tie point. The position of the corresponding tie point in the second image is calculated by the use of the parameters found in the correlation routine. The major advantage of these artificial points is their high precision due to the fact that they are totally independent of the user. The repeatability is ensured to within one pixel.

4. THE RESULTING IMAGES

For later analysis we propose different images resulting from the above described routines. The detected crack patterns of the painting before transportation and the resampled ones recorded after transportation are superimposed and presented in false colour in order to allow a simple identification of changes. The changes highlighted in false colour are then extracted as small images as well as the corresponding original images before and after the event. Furthermore, in an overview image of the painting the locations of the detected changes are indexed by red spots.

5. PRESENTATION OF THE CASE STUDIES

As case studies we present the results from surveying two real transportations of paintings[12]. These were E.-L. Kirchner, Kartenspielender Knabe, oil on canvas on stretcher, 69.3 x 62.3 cm (Bayerische Staatsgemäldesammlungen München) and A. Sisley, La Route de Hampton Court, oil on canvas on stretcher, 38.8 x 55.4 cm Bayerische Staatsgemäldesammlungen München). Each had been packed into an insulated case consisting of soft fibre board, polyethylene cushioning, aluminium-laminated polyurethane foam plates and a plywood case. The Kirchner was transported by truck, the Sisley by truck and aircraft. For the Kirchner we acquired 5x8 sub-images (7MB each) and for the Sisley 5x4 sub-images. Figure 2 shows the false colour representation as well as the situation before and after the transportation of a detail from the Kirchner painting. We see a beginning loss of a small part of the paint layer. The regions on the painting shown in the figures are 5x5mm. Figure 3 shows the prolongation of a crack. Figure 4 and figure 5 show prolongated cracks found in the Sisley painting. The regions on the paintings shown here are 5mm large. Figure 6 (5x8 mosaic) shows the locations of the detected changes in the Kirchner painting and figure 7 (5x4 mosaic) in the Sisley painting. All these detected changes have to be analysed and great care has to be taken when interpreting them.

6. CONCLUSION

The traditional methods for assessing the condition of paintings could be improved significantly by our method. The results presented above show that microcracking as well as deformations can be detected by our approach. The assessment of transportation damage continues and we hope to simplify as well as to speed up the procedure for easy use in museums.

7. ACKNOWLEDGEMENTS

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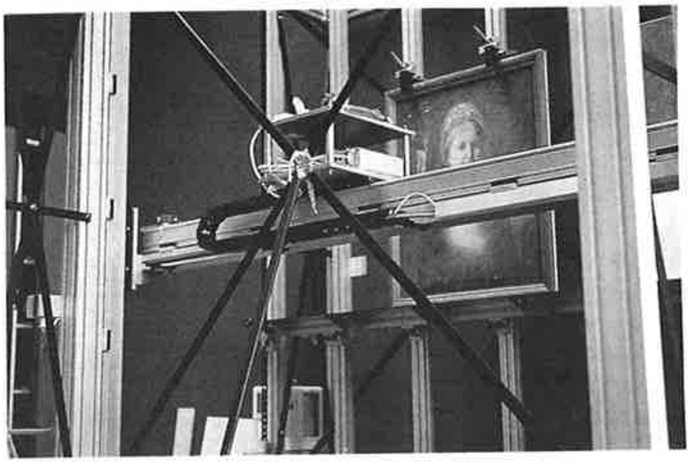

Figure 1 The acquisition system

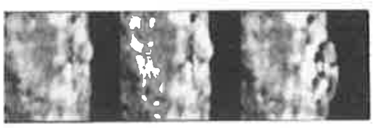

Figure 2 Beginning loss (Kirchner)

Figure 3 Prolongated crack (Kirchner)

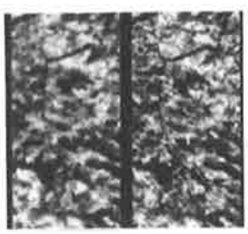

Figure 4 Prolongated crack (Sisley)

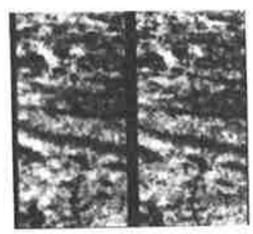

Figure 5 Prolongated crack (Sisley)

Figure 6 The detected changes in the Kirchner painting

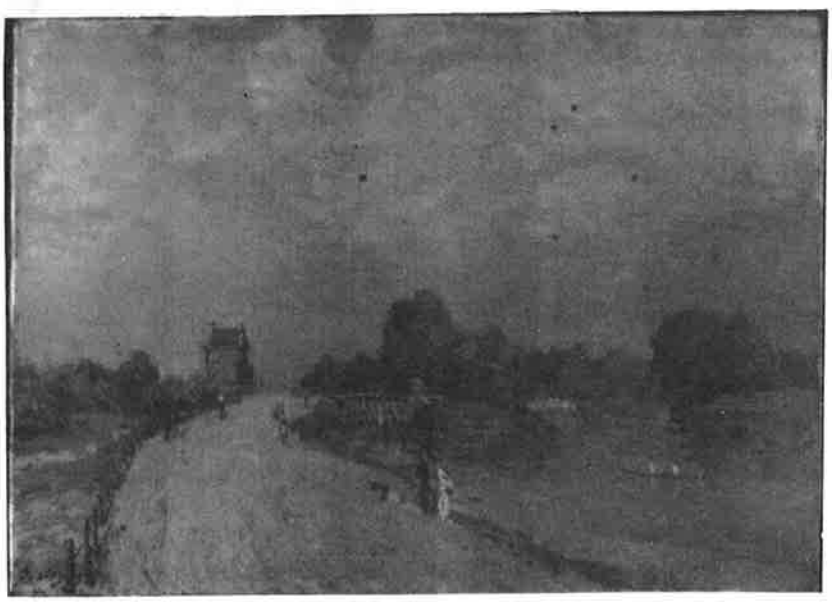

Figure 7 The detected changes in the Sisley painting