Monitoring of oil paintings by means of optical 3D scanning

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Abstract. A novel technique of monitoring of painted surfaces is proposed. Experimental results concerned with use of optical 3D scanning for monitoring of oil paintings are presented. One of oil paintings with collection of The Military-Historical Museum of Artillery, Engineer and Signal Corps (St. Petersburg, Russia) was scanned by means of optical 3D scanner, which operates using structured light. The scanning was carried out 2 times with time interval of 4.5 years. In both cases we created computing 3D models of the same painting. These models were compared using software GeomagicStudio that allowed to get a precise quantified information about deformations of canvas and frame of painting.

1. Introduction

Artifacts of history and culture, regardless of whether they are exhibited (in the open air or stored in museum collections), are gradually destroyed over time. This happens under the influence of adverse environmental factors, whose impact has increased significantly in recent decades due to a dramatic environmental deterioration. In this situation, regular monitoring of the state of conservation of artworks is becoming an increasingly urgent task in the field of preserving cultural heritage. In case of paintings, the need for monitoring is associated with the fact that defects in the paint layer usually occur at the “micro level”, and it is very difficult to detect them in a timely manner using photography (including high resolution one) which is traditionally used in museums to monitor the state of paintings.

One of the possible approaches to solving the problem of paintings monitoring is the use of laser and optical 3D scanning technologies. Currently, this technology is widely used to document the paintings. There are known cases where it was used to monitor stone monuments [1], [2], as well as mural paintings. In particular, one of the authors of this article showed the principal possibility of using 3D scanning to monitor the state of wall paintings to control the “swelling” and the width of the cracks of the plaster layer [3]. However, there is no information on the use of 3D scanning for monitoring oil paintings in the scientific literature. This suggests a scientific novelty of research conducted in this work.

We carried out experiments on monitoring the painting “Equestrian artillery company No. 13 barrages French columns during the retreat of the “great army” from Russi” (created by Russian artist P. Karyagin, 1912) from the collection of the Military-Historical Museum of Artillery, Engineer and Signal Corps in St. Petersburg. Its general view is shown in Fig 1. The choice of this painting as an object of study was connected with that fact its surface has a complex relief. This artist is characterized by the “volumetric” style of painting technique, which is manifested in the application of the paint layer by separate textured strokes of different thickness and width. It allows one to easily capture the 3D relief of the painting’s surface and track the changes of the paint layer’s state as the relief changes during the reference time interval.
2. Measurements

In the process of experiments, the surface of the painting within a separate control area of 149.3 cm\(^2\) was scanned using an optical 3D scanner Cronos 3D (manufacturer – Open Technologies Ltd., Italy) in 2014. The surface geometry capture mode with texture (the surface geometry capture mode with texture was chosen) was used. This scanning mode was used to simplify the process of assembling the scans of the painting into a single computing 3D-model at the stage of processing the data obtained in the scanning process. Though the surface of the painting has an individual relief, but its geometry is complicated for aligning the scans. However, combining the same texture maps may sufficiently simplify the process of assembling 3D model and increase the accuracy of aligning the scans.

In 2019, we re-scanned the same section of the painting. In the course of this work optical scanner RangeVision ProSM (manufacturer – RangeVision, Russia) was used.

3. Experimental results

To verify the possible changes in the geometry of the painting over the past 4.5 years, a specialized computing software Geomagic Studio 2012 was used to proceed the data obtained in the process of 3D scanning. With the help of this program, a comparison of 3D models of the picture obtained in 2014 and 2019 was made. This comparison was made by combining the obtained 3D models, which allowed to visually and quantitatively estimate the deviation of the surfaces of the paint layer of the picture fixed in one and the other model. The program allows you to create a color scheme, which displays the value of different colors deviation 2 compared surfaces relative to each other. In this case, one of the surfaces is selected as a reference. In this case, the areas of the said color scheme, represented by shades of blue, are below the reference surface, and areas of red – above the reference surface (see Fig 2).

To obtain the most correct data, firstly the surface of the paint layer from the 3D model of 2014 and then 3D model of 2019 was chosen as the reference surface. In both cases, similar results were obtained.
As a result of the experimental studies it was shown that the control section of the canvas has 7 zones of yellow and blue colour shades (each of them is an area of about 13.5 cm², one of them is shown in Fig 3 by red color), which indicates the presence of deviations of the order of 200 micrometres in greater or lesser sides (i.e., there are "swollen" and concave areas. Since these irregularities are distributed throughout the study surface, it can be concluded that the nature of the deformations of the canvas is wavy.

A similar method was used to monitor the wooden frame of the painting. As a control zone, the lower right corner of the picture was chosen, where there is a crack at the junction of the vertical and horizontal sections of the frame. During the control period of 4.5 years, the gap has increased significantly – when matching 3D models in the Geomagic program along the entire length of the slit, a blue area with a...
width of about 0.4 mm is clearly visible (see Fig 4). As for the frame itself, it should be pointed out that there is a "redness" of the surface of the polygonal grid closer to the edge of the frame as well as presence of a blue area near the joint of the frame and the canvas. Such a distribution of color may be evidence that the edge of the frame began to bend inward - toward the painted layer.

![Figure 4. Visualisation of difference between two 3D-models of wooden frame](image)

4. Conclusion

Thus, as a result of the experiments, the principal possibility of using 3D scanning for monitoring oil paintings was demonstrated. It was shown that this method allows one to control the state of the surface of the painted layer as well as the wooden frame with high accuracy (fractions of a millimeter). Such information can be useful for the conservators of paintings to decide on the need to change the conditions of storage and exposure of paintings.

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References

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