Digital Restoration and Preservation of Deteriorated Mural Paintings by Advanced 3D Measurement Technologies

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Abstract. The external factors from nature are responsible for weathering of different monuments and cause considerable deterioration of Old mural Paintings. This paper presents a virtual reconstruction scheme useful for subsequent restoration processes of the degraded versions of the murals from Matia Loggia, Corvins'Castle, Hunedoara, Romania. The analysis of materials and techniques and the possible deterioration mechanisms are discussed, too, correlated with the colour digital photography and mapping of visible painting degraded area were conducted.

Keywords: Restoration, Preservation, Mural Paintings.

1 Introduction

Image processing techniques is a relatively new item applied to analysis, preservation and restoration of artwork. Except by other traditional techniques, ancient paintings from cultural heritage can be preserved by computer technologies. These paintings could be deteriorated mainly by different weather agents or human interventions, which cause breaks in the paint, or varnish (Adriano, Silva, Veiga, Mirão, & Candeias, 2009).

At Corvins'Castle, from Hunedoara, Romania, the fresco (Matia Loggia), as one of the most impressive mural paintings from this castle, which dates back to the end of the 15th century (Bodochi, 2008; Bogdan, 1970). This monument is in danger of disappearing because of its degradation stage, it being almost erased due to time degradation (Akyuz, Akyuz, Basaran, Bolcal, & Gulec, 2007; Artioli & Angelini, 2010; Bersani et al., 2009; Burgio & Clark, 2001; Cardell, Guerra, Romero-Pastor, Cultrone, & Rodriguez-Navarro, 2009; Casadio, Daher, & Bellot-Gurlet, 2017). The previous chemical, physical and mechanical data obtained from some analytical techniques, offer to the archaeologists the informations about the material composition and manufacturing technology of such objects, as follows: X-ray diffraction (XRD) and scanning electron

microscopy (SEM) with energy-dispersive spectrometry (EDS), FTIR, Raman, chromatic parameter measurements (R. Ion et al., 2018) used for analysis of paints and pigments and for the evaluation the weathering/ deterioration processes of the investigated artifacts.

2 Experimental Part

The murals were photographed using a digital camera. Image processing and 3D diagram construction was done with MatLab R2016a software. As the origin of the name Matrix Laboratory shows, the matrix is the way data is manipulated and represented. Any image can be defined as a two-dimensional array in which each pixel has its specific position and the value of the intensity of that pixel depends on the 3 values in the RGB (RedGreenBlue) system. Figure 1 shows how the algorithm works. Starting from a color image of the murals, a color elimination takes place by passing images from the RGB system in gray scale. Then the texture is created and extracted to recognize the distortions, followed by a segmentation of the images. In the final steps, a reconstruction of the image is performed, the background of which was highlighted with the help of the 3D diagram. By a mathematical correlation z axe could offer the quantitative morphological changes of the surface. Also, ImageJ free software has been used for evidencing the damaged area with changed color.

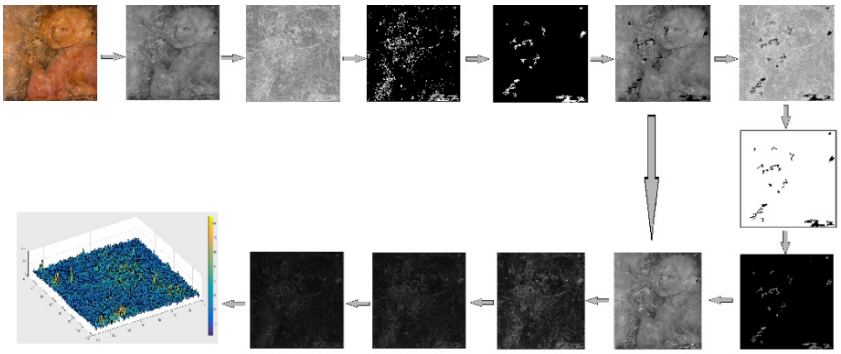

Fig.1 Algorithm steps of MatLab

3 Results

Usually, a wall is made from stone blocks bound with a mortar made of clay and lime. The arricio is rough and composed of lime and fine aggregates of quartz and volcanic stone, while the intonaco is very fine and thin, made from lime and clay and fine aggregates of phytoliths, quartz and volcanic stone.

In antiquity some mineral pigments has been used: hematite (reddish, orange, purple, and brown), goethite (yellow), lepidocrocite (brown), calcite (white), dolomite (white),

celadonite (green), malachite (green), and quartz (translucent and white) (Castro, Sarmiento, Martínez-Arkarazo, Madariaga, & Fernández, 2008; De Faria, Venâncio Silva, & De Oliveira, 1997; Derrick, Stulik, & Landry, 1999; Eastaugh, Walsh, Chaplin, & Siddall, 2007).

Mural imitating is a major method for ancient murals conservation and research (Genestar & Pons, 2005). Many researchers tried to restore the damaged portion of murals and the missing regions from the murals with objectivity and precision style. Numerous techniques were proposed for image inpainting and image completion, and they have been successfully applied in digital photographs and paintings. However, they have difficulties in restoring facial image in ancient murals. Firstly, the style of line drawing in ancient murals are paintings.

Matia Loggia was built during Mathias Corvinus time in Transylvania's 15th century. The most notable expansion took place during Prince Gabriel Bethlen, in the 17th century, who built more towers and brought important changes to the architectural style of the castle. Matia Loggia includes few murals currently damaged. Some previous our publications revealed the damaged pigments (R.-M. Ion, L. Iancu, R.-M. Grigorescu, et al., 2018; R.-M. Ion, L. Iancu, D. Turcanu Carutiu, et al., 2018; R.-M. Ion, T. Nyokong, et al., 2018; R. Ion et al., 2018; Ion, 2016). The primary interest is to perform the image analysis at this point in order to obtain the current status of the artifact. Then, the data will be used to perform comparative analysis with older images with significantly better quality. The most relevant analysis in this case is chromatics. The original image and the color-labeled regions are presented (Moropoulou, Bakolas, & Bisbikou, 2000).

In this paper, it is presented an interactive image completion method for images that is based on semantic image database of Matia Loggia murals. All the illustrations, including charts and photos, are labelled as in Figure 1.

By substracting different colours, is possible to identify the degree of damage will be obtained from the 3D diagram, especially the area with efflorescence. The values on the Z axis reflect the intensity of this process. The expression of the results of the quantitative analysis can be done with the function MCV (Morphology Change Value). For example on the image that represents the mural "B" has the dimensions of 1080 x 3443 pixels, therefore there are 3 718 440 points in a 3D diagram (1080 lines and 3443 columns). The values on the Z axis will reflect the intensity of this process. The expression of the results of the quantitative analysis can be done with the function MCV (Morphology Change Value). For example on the image that represents the mural "C" has the dimensions of 1080x3443 pixels, therefore there are 3 718 440 points in a 3D diagram (1080 lines and 3443 columns). Mathematical expression of MCV= $\frac{1}{3\,718\,440} \cdot \sum_{\substack{1\le i\le 1080 \\ 1\le j\le 3443}} |B_{ij} - A_{ij}|$, where Aij represents the value of a pixel in conditions that do not affect the mural painting (humidity in normal parameters ≈ 35 % and salt concentration ≈ 0 %) and Bij represents the value of the pixel in conditions that affect the mural picture (humidity ≈ 78 % & high salt concentration ≈ 10 %). The warmer and more lighted the color from processed images (3D diagrams), the more accentuated the degradation is in that area (Figure 2).

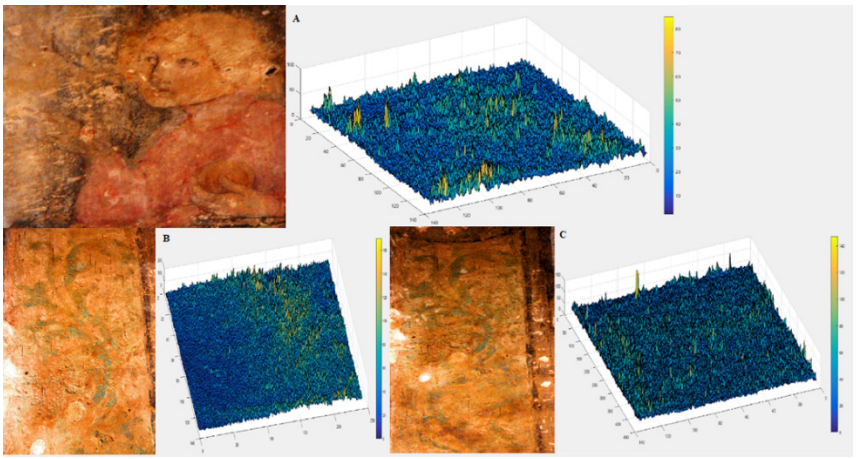

Figure. 2. MatLab processing images of the 3 mural paintings from Matia Loggia

The observation and recording of the aspects of the pictorial surface allows the extraction of data regarding the technical pictorial execution of the work, it`s state of conservation and previous restorations (Santamarina-Campos, Carabal-Montagud, de Miguel-Molina, & De Miguel-Molina, 2017). This information can also be used to analyze certain parameters related to the potential future restoration of the painting, such as the amount of material that will be used to fill the gaps, or the amount of dye that will be applied to the surface. The more damaged the area in the painting, the more amount of substance is used. Surface analysis has been achieved by MatLab and ImageJ offer clarifications on the same damaged area, especially on missing pigments from the painting surface, Figure 3.

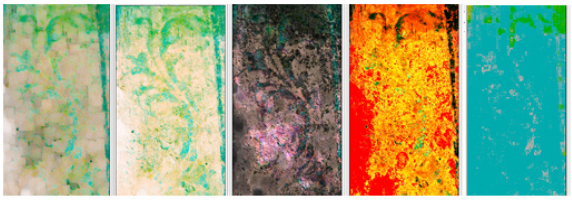

Figure 3. Evidence of the mural painting's degradation by ImageJ software.

General in-painting techniques cannot complete these complex structures in the missing regions. The areas affected by the efflorescence appear in the presented images in the form of white or slightly yellow areas; however, the areas with pigments or paints degraded appear as white veil. All this information can be useful to restorers who aim to restore the paintings in this monument.

4 Conclusions

In this paper has been treated the aspects of the pigments prelevated from the Matia Loggia of Corvins' Castle, in order to collect informations about the weathering/deterioration processes of this mural paint. The major constituents and their provenance have been identified and discussed in correlation with ImageJ and MatLab programs, through interactive image completion methods based on semantic image database of Matia Loggia murals. The field of image processing has developed out of the need that certain surface changes cannot be detected with the naked eye and therefore a mathematical processing of things is needed.

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