10.21611/qirt.2016.030

Thermographic survey of frescoes with different thermal stimuli: a PLS-based analysis

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Abstract

Infrared thermography is a well-known technique for the non-destructive evaluation of artworks. In recent times, several image processing algorithms have been proposed and studied to enhance the detection of defects. Amongst them, post-processing methods based on Partial Least Squares (PLS) have shown good results in terms of reliability and detectability of defects. This work analyzes the available PLS-related algorithms for the evaluation of a fresco sample with known defects, stimulated with different heating sources. The results are compared in terms of Signal to Noise Ratio and Receiver Operating Characteristic curves.

1. Introduction

The advantages related to the application of Infrared Thermography (IRT) in the field of non-destructive testing and evaluation have been presented to the scientific community since long time [1]. IRT is widely utilized for the analysis of different materials and components, and its non-invasive and contactless nature promotes it as a suitable technique for the inspection of artworks [2]. Cultural heritage is typically surveyed to find hidden structure or information, to determine the presence of moisture related damage, to locate delamination or detachments [3]. The standard inspection procedure consists in imposing a heat flux on the object and measure the related temperature variation with a thermal camera. The obtained thermal images results are successively processed with dedicated algorithms. Several options are available in the literature [4] and in recent times PLS-based methods have shown good results both for industrial applications [5] and for cultural heritage, especially for frescoes [6].

2. Materials and methods

The analyzed fresco specimen is a plaster panel sizing 68 x 50 x 5 cm. The panel surface has been divided in twenty sectors, painted with different colors. Under the surface 32 defects have been created, inserting circular inclusions of polystyrene of diameter 1.5 cm and thickness equal to 1 mm. Two different testing procedures have been applied to the specimen. In the first one a traditional pulsed heating, delivered by lamps, has been applied. In the second one, a Pseudo Random Binary Signal (PRBS) was sent to the lamps that generated a series of short heating steps turning on and off the lamps. This technique minimizes the temperature variation of the specimen, that is a primary necessity when dealing with cultural heritage. In both cases a thermal camera (FLIR 655 SC, spectral range from 7.5 to 14 μm, declared thermal sensitivity of 30 mK) recorded a sequence of thermal images at 1 hz, for 4-8 minutes depending on the heating source.

The acquired images have been analyzed with PLS-based techniques. PLS is a statistical method that integrates Principal Component Analysis and Multiple Linear Regression. The basic equations of PLS are

$$X = TP^T + E \tag{1}$$

$$Y = TQ^T + F \tag{2}$$

The data matrix could be the X or the Y matrix, leading in the first case to the PLST approach and in the second case to the PLSRT approach [6].

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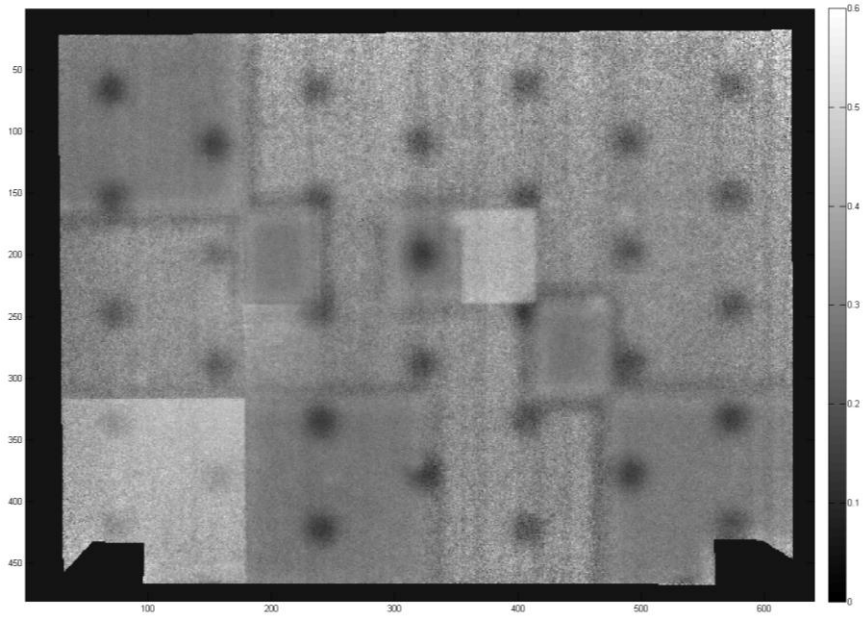

Fig. 1. *Result of the Partial Least Square Thermography algorithm applied to the fresco specimen stimulated with a pulsed heating.*

As the defect map is known, the results obtained on the specimen under two different heating conditions and with the different PLS-based post-processing techniques have been compared on the Signal to Noise Ratio, to determine the effectiveness of the method, and with the Receiver Operating Characteristic curves, that give a measure of the reliability of the method quantifying its sensitivity.

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