Terahertz Imaging for Painting Analysis

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Advanced imaging techniques are becoming increasingly important in the analysis of paintings. Specifically, art experts routinely use IR reflectography and x-rays. IR reflectography, either performed by means of standard Si CCD, vidicon camera or other InGaAs detectors, operates at wavelengths from 800-1100 nm, 800-2000 nm or 800-2500 nm, respectively, allowing it to partly penetrate the visible paint layers to uncover hidden components or underdrawings in the painting. By contrast, x-rays operate at much shorter wavelengths than visible light; different materials absorb x-rays differently (*e.g.*, paints that contain heavy atomic elements such as lead white or vermilion red absorb x-rays more than other paints). The different techniques greatly differ in the kind of information they reveal and complement each other.

In this study, we investigate the use of terahertz imaging for the analysis of paintings. Terahertz waves, with a much higher wavelength ranging from about 1 mm to 0.1 mm, are able to penetrate the paint layers much deeper than IR radiation. Compared to x-rays, THz waves are non-ionizing because they do not have enough energy to knock electrons off atoms, being, thus, safe for both artworks and users. The material specific interaction, which differs from other wavelengths, gives complementary information concerning the paint layers composition.

Despite its potential, hitherto, terahertz imaging has hardly been applied in painting analysis primarily because of its high costs. We developed a new, cost-effective system for terahertz imaging that makes this technology much more accessible to art experts. In this study, we present the details of our new system, as well as images obtained with our system of artificial samples (made with early 20th-century paint materials) and of an anonymous still life, using up to 221 different frequencies. In addition, we present the results of experiments on the artificial samples with classifiers that are trained to recognize whether or not a certain type of paint is present at a particular location on the canvas based on the terahertz response spectrum measured at that location. The results of these experiments provide insight into what types of paints can be identified based on terahertz images, and what types cannot be distinguished.

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007- 2013) under grant agreement no. 600849 (INSIDDE).