IMAGING OF GOLD RENAISSANCE PUNCHWORK USING THREE - DIMENSIONAL OPTICAL COHERENCE TOMOGRAPHY

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Introduction

Optical Coherence Tomography (OCT) is an imaging modality which enables reconstruction of the spatial structure of examined objects.[1] It uses low power, near infrared (NIR) light to interferometrically measure distances between layers inside the sample. OCT is a non-contact and non-destructive technique which achieves micron-scale imaging resolutions. Therefore, OCT is well-suited for examining fragile works of art which often have fine layered structures, possess unique historical value, and inherently require safe analysis methods to avoid damaging the sample.[2-12]

In our report, we show examples of three dimensional OCT (3D-OCT) imaging of gold punchwork in Renaissance panel paintings.[13] Punchwork is an art decoration technique which uses small tools with different shapes to adorn various works of art with ornamental motifs. One example is the impressions of punches in gilded panel paintings from the early Italian Renaissance. The techniques of embellishing halos and garments with punches were developed in different workshops, spreading from Italy to Bohemia and France. Analysis of punchwork is important for studying the development of workshops, origination of paintings or attribution of specific works to different artists.[14,15] 3D-OCT imaging of punchwork may provide valuable information for studying the history of paintings.

Experimental setup

For imaging of gold punchwork, we used a 3D-OCT instrument with a Fourier domain mode locked (FDML) laser as a rapidly tunable light source.[16-17] The laser operated at sweep repetition rates of 42,000 sweeps/s. The center wavelength of emitted light was 1287 nm. The tuning range was 118 nm, providing an axial imaging resolution of ~6 µm in varnish or paint. With ~10 mW of power incident on the sample, we achieved an imaging sensitivity of 100dB. As an imaging platform, we utilized a modified OCT microscope (Thorlabs, Inc.). The beam spot size was ~30 µm which defines the transverse imaging resolution. The working distance of the microscope was ~3 cm.

Results

We imaged punchwork in two Renaissance panel paintings created by the Master of the Orcagnesque Misericordia active between 1375 and 1400 AD (“Marriage of the Virgin” and “Coronation of the Virgin”) and in one copy of a Renaissance painting “San Marco”, produced by Daniel V. Thompson Jr around 1920 using the punch tools of Frederico Ioni, a well known restorer and notorious forger of Italian Renaissance art.[18] We imaged several punch marks characteristic of these paintings. The three dimensional data sets acquired in these regions consist of 800 x 800 x 512 pixels in horizontal, vertical and depth (or axial) directions. The imaged volumes are 4 mm x 4 mm x 3 mm. We utilized a commercial 3-D rendering software (ResolveRT, Mercury Computer Systems, Inc.) for visualization of the OCT data. We used several data display methods for visualization of features characteristic of the punch marks. For example, projection OCT images generated by axial summation of the 3-D data sets are used for identification of the imaged areas in the painting. In addition, they can be correlated with photographs and therefore allow for registration of cross-sectional images with the details visible in the surface of the painting. Cross-sectional OCT images enable measurement of the depth of

punches. Volume rendering can be used to generate three dimensional virtual models of the punchwork. Such visualization allows for intuitive assessment of spatial distribution of punches, their shapes and depths. *En face* slices selected at different depth-locations of the 3D data sets at increased depths reveal the shape of punches and therefore also the form tools used for their creation.

The results of our study show that 3D-OCT instruments are well-suited for applications in imaging of the gold punchwork. Infrared light used in the OCT technique has the ability to penetrate through different materials used for creating works of art. Although the gold foil used as the base material for punchwork is nearly 100% reflective for a very wide range of wavelengths (including NIR), it is not uncommon to find layers of aged varnish or paint on the top of the punch marks. 3D-OCT enables correct recognition of the gold layer located beneath other materials. The high imaging speeds of swept source 3D-OCT instruments using FDML lasers enable high-density transverse optical scanning of fine punchwork structures in short times. This allows reconstruction of high definition three dimensional virtual models of examined objects. Punch marks can be analyzed quantitatively. Their contours can be examined for presence of defects in tools used for their execution. Such microscopic imperfections could serve as “fingerprints” allowing for tracking the tools as they were shared or handled down by different workshops or artists.

Conclusions

In conclusion, the results of our feasibility study show that 3D-OCT can be used for examination of paintings containing gold punchwork. OCT may enable the recognition of specific tools used for execution of different works and therefore give insight into the origination of paintings. Attribution of different works to the same artist may be possible after more detailed analysis of multiple paintings and punches. Verification of possible forgeries could be also attempted using systematic 3D-OCT study of punchwork.

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