MICRO COMPUTED X-RAY TOMOGRAPHY APPLIED TO BOWED STRINGED INSTRUMENTS

Francesco Piasentini (1), Andrea Scanavini (2)

1. PhD, Material Engineer & Violin maker, Padova, Italy; 2. TEC-Eurolab, Modena, Italy

Introduction

This paper investigates some applications of industrial micro-Computed X-ray Tomography (or micro-CT) to bowed stringed instruments.

When compared to clinical CT, this technique shows great improvements in terms of spatial resolution:

1. diagnostics of damages and reparations can be performed at a higher degree of accuracy and reliability
2. 3D surfaces can be extracted, analysed and saved with a resolution better than 50 μm

Both diagnostics and metrology represent applications of micro-CT for bowed instrument's appraisals and evaluations. Museums, dealers and collectors can obtain detailed reports of their valuable collections. Results from micro-CT can also be shared worldwide between experts, i.e. in order to refine knowledge about a certain regional style in a violin's craftsmanship. Even dendrochronology can be performed on micro-CT images.

Methods

Clinical x-ray Computed Tomography (or CT) has been intensively used in bowed instruments investigation in the last 25 years [Sirr, 1999].

Many authors reported the use of this method for the evaluation of an instrument's condition in terms of: worm damage, repairs. Clinical CT has also been used for metrology: plate thickness mapping and curvature profiles, bass-bar position, wood density evaluation [Loen 2005, Borman, 2009]. Recently, synchrotron radiation has been successfully used to investigate on violins [Zanini, 2010] opening new horizons on the use of micro-CT on musical instruments.

On the other side, industrial CT has become an invaluable method for non destructive examination of products. Its application varies from quality control, reverse engineering and metrology. When its spatial resolution is below 50-100 μm it is called micro-CT [Stock, 2009]. This performance has been initially obtained with synchrotron radiation, until commercial tube-based systems have been introduced to the market.

Recent commercial tube-based micro-CT systems can have system resolution of 0,5 μm, and can accommodate instruments of the dimension of a cello. These systems overcome many of the limitations of clinical CT, which is devoted to the analysis of living tissues:

1. focal spot size can be lowered down to a few microns, with great advantages on the image quality
2. exposure time can be increased to obtain adequate photon count, to compensate for the lower beam current
3. relative position of specimen, source and detector can be varied, in order to obtain the best spatial resolution for a given specimen dimension

In this article we present the results of investigations carried out at TEC-Eurolab (Modena, Italy), using a North Star Imaging X5000 equipped with a XrayWorX microfocus X-ray source. In Table I, it is possible to evaluate the differences in working condition between the clinical CT and industrial micro-CT reported in this article. Values between brackets refer to the second example (violin pegbox, Figure 4-6)

Type	*Resolution [μm]*	*Voltage [kV]*	*Current [mA]*
Clinical CT	*670*	*120*	*99*
Micro-CT	*89 (70)*	*50 (65)*	*1.6 (0,52)*

Table I: working conditions

Results

The first example is a 3D rendering of a violin top plate, seen from the inside. 1260 images have been taken with a resolution of 89 μm.

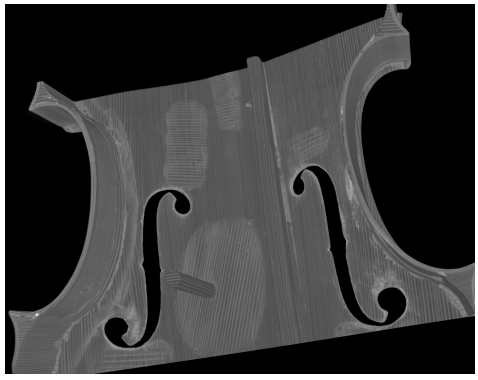

Figure 1: 3D rendering of a violin top plate

The quality of the 3D reconstruction can be appreciated in the details of Figure 2. Wood patches, edge doubling and hide glue drips can be easily recognized.

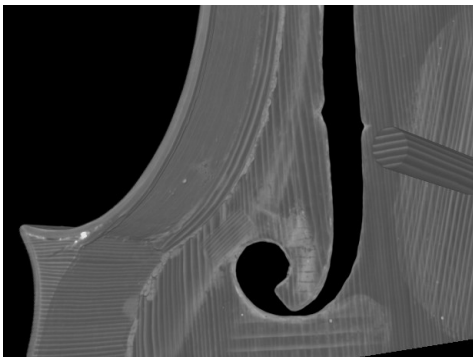

Figure 2: details from the same 3D reconstruction

Another interesting application of micro-CT is wood dating by means of dendrochronology. In Figure 3, is represented a detail of an axial section of the same violin. Spruce growth rings are clearly visible.

Their position and dimension patterns can be used to determine the age of the wood, helping to date the instrument's manufacturing age. Dendrochronology has been intensively used for dating instruments [Ratcliff, 2012].

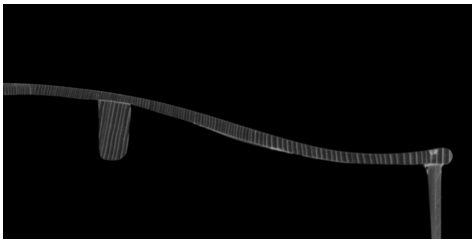

Figure 3: details of an axial section

In the second example, a violin scroll, badly repaired, has been scanned at 70 µm.

Due to the higher x-ray absorption coefficient, hide glue can be easily distinguished from wood. In figure 5, on the right side, it is clearly visible the hide glue layers between the original wood and the two patches. The bottom of the pegbox presents a generous layer of filler.

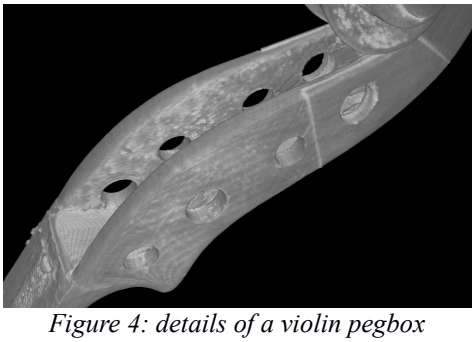

Figure 4: details of a violin pegbox

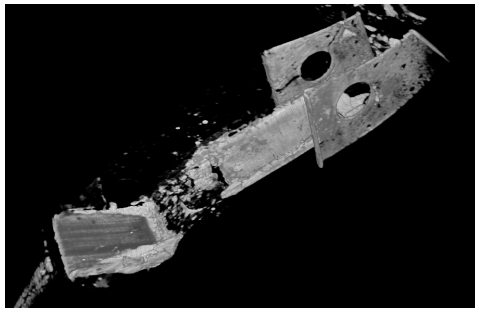

Figure 5: hide glue and filler, in the same pegbox

It is interesting to compare results from clinical CT and micro-CT. An axial section of the violin pegbox of Figure 4, taken with the two different systems, is presented in Figure 6.

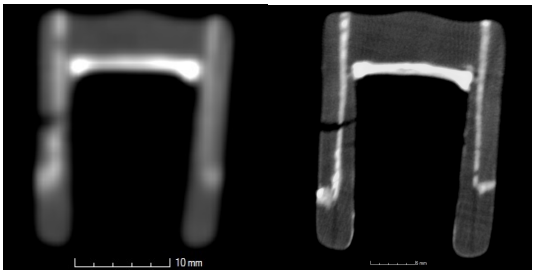

Figure6: Comparison between clinical CT (left) and industrial micro-CT (right)

Discussion

The use of a micro-CT tube-based industrial system has given interesting results when applied to violin analysis. Possible applications vary from defective diagnostics (wormholes, previous repairs), geometric reconstruction and dendrochronology.

Micro-CT can be successfully used to take a precise snapshot of the condition of valuable instruments, and to certify their condition also inside the material.

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