Assessing Musical Instruments Conditions Before and After Restoration Using Industrial X-Ray Ct (iCT)

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Abstract

Assessing the conditions of a musical instrument is the first step in any conservation and restoration activity. Being a delicate artefact made of wood, various factors can compromise their conservation and their functionality: from improper use and handling, woodworm's attacks, abrupt variations in the material moisture content, to non orthodox restorations and repairs. Evaluating the effects of these factors is a crucial point when making a condition report of an instrument. Industrial Computed Tomography (iCT) has proven to be an effective tool in documenting evidences of damages and modifications. In this work we present an example of the flexibility of the iCT. A portion of a violin was scanned at various resolution (112, 224 and 447 mm) and a comparison among these results was performed. An example of decision-making in violin restoration supported by the use of iCT is also reported.

1. Multi-resolution iCT and Diagnostics

TEC Eurolab is a leading company in NDT, since 2014 is working on the application of iCT to cultural heritage. Diagnostics of Bowed Stringed Instruments can be performed with two different iCT systems: NSI X5000 and NSI X7000. A typical scenario is the full-scan at 112 microns of a complete violin. For a given Multi-resolution system, a smaller voxel size means also longer acquisition time and bigger dataset to deal with. The average dataset dimension for a whole violin scanned at 110 microns is 20 Gb. The voxel size can be tailored to the requested application, either focusing the analysis with a small voxel in a certain region of the instrument or using a bigger voxel for a quick analysis of the whole instrument. Further flexibility is given by the possibility of using the so-called "binning" mode. In this approach the x-ray detector area is divided into 2x2 (or 4x4) pixel groups, each of them acquiring data as a single pixel. The acquisition time is respectively 4 (or 16) time faster, at the cost of a voxel size increased by a factor of 2 (or 4). A region of a violin body (measuring approx. 100x230x170 mm) was scanned using different resolutions. Data are summarized in table I.

mode	Voxel size [mm]	Dataset dimension [GB]	Scan time [min]
4x	447	0.08	3
2x	224	0.77	6
1x	112	5.8	24

Table I: *effect of voxel size on dataset dimension and scan time*

At 447 mm the wood structure is not resolved, but the biggest defects are clearly visible. This resolution is useful for a fast identification of defects starting from 0,5-1.0 mm and with a strong radiographic contrast, such as for holes or very dense filler materials.

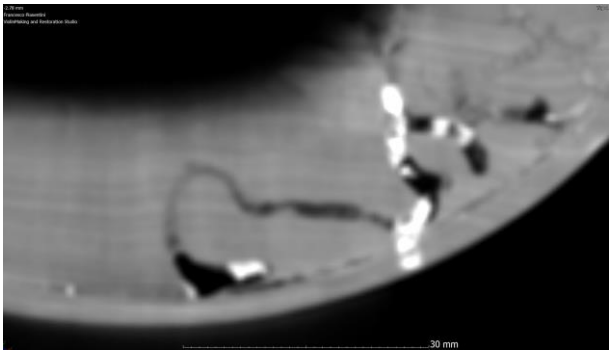

Figure 1: *Coronal section of a violin back. Voxel size: 447 mm (4x mode)*

The intermediate resolution allows the wood growth ring identification. Features such as the residual of the woodworm attack are now visible. Filler material morphology (areas with the higher grey value) turns out to be porous. Finally, the standard voxel size gives the best representation of both the wood structure and the defects, as reported in figure 2.

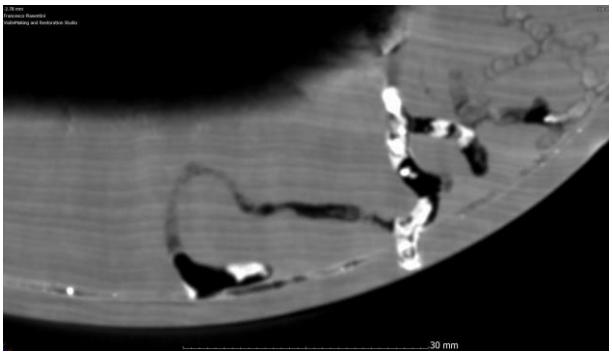

Figure 2: *Coronal section of a violin back. Voxel size: 224 mm (2x mode, or "binning")*

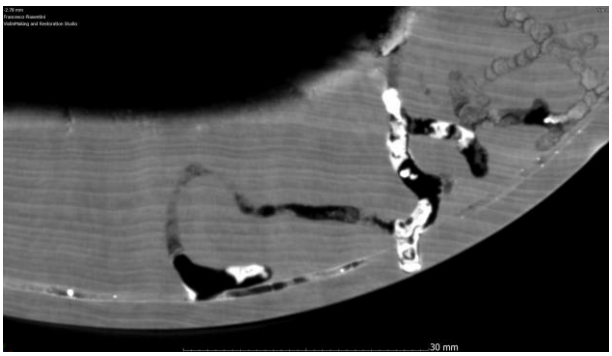

Figure 3: *Coronal section of a violin back. Voxel size: 112 mm*

2. iCT and decision-making in violin appraisals and restorations

Old and valuable violins present various degree of damage and presence of previous restorations. The intrusiveness of these interventions is not always assessed from an external investigation, even when the instrument is disassembled. When planning a restoration activity, the process of decision-making is often between leaving the old restorations or replacing them. In this process iCT plays an important rule, because it allows to determine the extensions and depth of both damages and previous restorations.

Another example is reported in Figure 5. A suspected woodworm damage on an Andrea Guarneri violin turns out to be a re-composed fracture, with missing fragments lost during the previous restoration.
The iCT analysis, performed at 68 mm, showed that no woodworms damage is present.

Figure 5-6: *Suspected wood-worms damage on an Andrea Guarneri violin (Courtesy Franco Simeoni)*

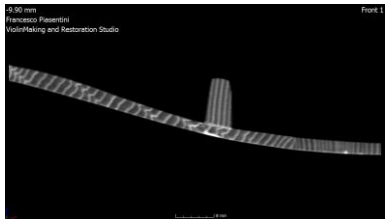

Figure 7: *axial slice of the corresponding area, voxel size 68 mm*

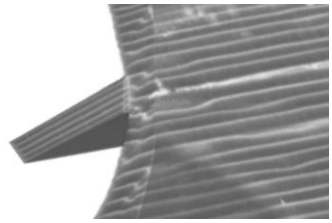

Figure 8: *3D volume rendering showing sections of the region of interest.*

3. Assessing the quality of restoration activities

Another explored application of iCT is the assessment of the quality of restoration activities. CAM milled wood patches are becoming an interesting alternative to traditional techniques.
A portion of a violin was scanned at 70 mm, and the quality of the restoration performed using CNC milled patches was investigated in terms of porosity and glue layer thickness. Original wood is denser (see bottom of Figure 9: higher gray values stand for more x-ray absorbing material). Glue lines are visible in the original wood.

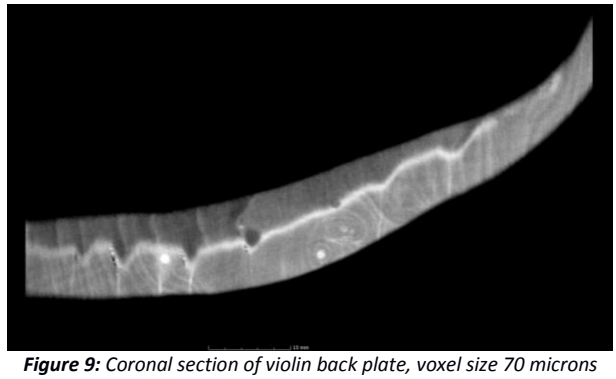

Figure 9: *Coronal section of violin back plate, voxel size 70 microns*

Finally, a Giuseppe Guarneri “del Gesù” violin top plate was scanned in order to evaluate the thickness of the original material under a patch. Results guided the restorer in the subsequent restoration activities.

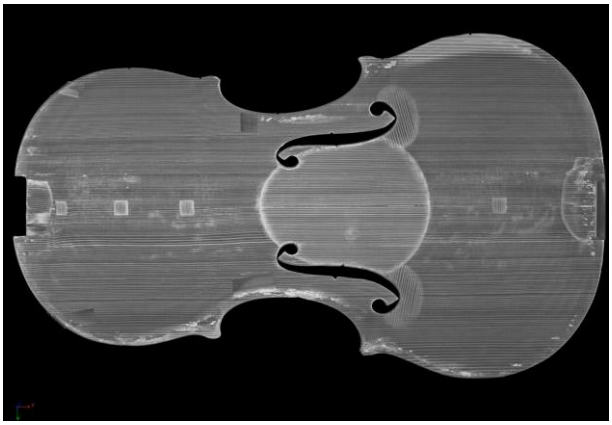

Figure 10: 3D volume rendering of a Guarneri "del Gesù" violin belly (Courtesy Eric Blot)

4. Conclusions

Industrial Computed Tomography is becoming a standard in the evaluation of string instruments condition.

It is actually the only non-invasive method that allows to assess damages and previous restoration invasiveness. Information from iCT can be used to minimize further restoration impacts.

Acknowledgements

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