MUSICES: Work in Progress on a Standard for Computed Tomography of Historical Musical Instruments

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Abstract
Digitalization of cultural heritage as a field of research becomes increasingly important. Within the project MUSICES, the Germanisches Nationalmuseum (GNM) and the Development Center for X-ray Technology (EZRT) of the Fraunhofer Institute for Integrated Circuits (IIS) are jointly developing a guideline for the three-dimensional X-ray Computed Tomography (3D-CT) of musical instruments. Various examples carried out during the project will ensure the applicability of the technical parameters. The work packages also include a classification of musical instruments with respect to their properties regarding X-ray imaging. Several measurements where conducted, including small and large brass, high resolution images of wooden parts, which are in the focus of dendrochronological examination. Elaborate experiences werde made with improved methods for acquiring an extended field of measurement in the frequent case of large instruments.

Keywords: Cultural Heritage, Computed Tomography, Image Quality, Musical Instruments

1 Introduction
The digitalization of irreplaceable objects of cultural and/or historical significance as field of research is gaining more and more importance recently (cf. e.g. [1-5]). The Germanisches Nationalmuseum (GNM) in Nürnberg, Germany, and the Development Center for X-ray Technology (EZRT) of the Fraunhofer Institute for Integrated Circuits (IIS) in Fürth, Germany, are jointly working in the MUSICES project, addressing issues of 3D-digitization of historically important musical instruments. Funded by the German research association DFG (Deutsche Forschungsgemeinschaft), the project partners draw up examination standards that, independent of the deployed devices and operating staff, are set to deliver high-quality 3-D volume data sets representing musical instruments. Plenty of representative examples carried out during the project ensure the applicability of the technical parameters. An international team of experts is advising the project team in their investigations.

2 Overall Concept
MUSICES is dealing with testimonials of the manufacturing of musical instruments during the last five centuries and aims at the fully 3-dimensional image acquisition of musical instruments with X-ray CT. From 2015 to 2017, more than 100 historically remarkable objects in the collection of the GNM will be digitized. The CT measurements are performed at the EZRT site in Fürth, where X-ray systems for radiation energies of between 60 and 9.000 keV are used for CT data capture and reconstruction, as well as means for multispectral material analysis and algorithms for the correction and evaluation of image data. Additionally, software tools are provided to optimize CT parameters via extended studies of simulated virtual data sets. Based on the evaluation of all resulting data sets, standard procedures are developed.

In order to systematize the measurements, the musical instruments are classified roughly into three groups, depending on the materials used in the specimen. These are purely wooden instruments like flutes and violins; purely metallic instruments, i.e. all brass; and mixed materials, above all wooden wind instruments with metal flaps and ornaments.

Within all these groups samples of very different sizes can occur. For example the “Viola da Gamba” (MI5) with more than 1000 mm height requires essentially different methods than a “Violin by Hummel” (MI419) which is less than half in length. In addition, there are the instruments which are complex in structure as well as material composition or which are solitary. This group encloses portable organs, automatically playing figurines or harps.

3 Preparation of the CT Examination
A first focus lies on preparation and planning of the inspection. Since the advanced industrial CT systems as well as medical scanners usually are not directly located inside a museum or archive, we look closely to aspects of transportation and packaging of an instrument, such that positioning and exposure with X-rays can be done without opening the protecting cover of the historical object. Also the fixing of a highly valuable object inside an X-ray cabinet for up to sometimes more than 24 hours is thoroughly scrutinized. Any vibrations, mechanical shocks and percussions shall be avoided, climatic changes exceeding the tolerances for humidity and temperature have to be precluded.

A second important task was to analyse in detail the motivations of organologists to perform a CT-scan of an instrument. In each case, the scientific queries post different requirements on image quality, which is quantified by spatial resolution, signal-to-noise and other physical measures.
4 Adaption of X-ray Technology and Data Acquisition Process

In order to adapt the involved X-ray technology and the data acquisition process to the actual necessities of the musical instrument inspection, the following tasks are under consideration:

- Acquisition of very large objects, like a double bass or a tuba. In this context „large“ implies that the object’s extensions exceed the size of the X-ray detector in at least one spatial dimension.
- Optimization of X-ray radiation characteristics, the sample’s orientation with respect to the X-ray field, and of acquisition parameters (e.g. number of angular positions). This optimization is done separately for the different instrument classes and use cases.
- Improvement of methods for a reliable and reproducible characterization of the materials present in the instrument. In particular, this applies to unusual materials like leather, wood, bone or other organic materials.
- Reduction of artifacts and distortions in particular with multi-material-objects. Additionally, for complex compositions, improvement and optimization of dual-energy techniques.
- Postprocessing, Visualization and Documentation

5 Use cases

The following list shows frequent reasons for CT-examination, based on the experience with almost 30 historical instruments:

- Quick inspection to check structural integrity: requires medium spatial resolution between 200 and 300 µm.
- Region-of-interest imaging to obtain information within a limited area of the instrument, such as adhesive bonds, damages caused by insects or moisture, or cracks visible on the surface.
- Full coverage of the whole instrument with accuracy of 100 µm or better to provide a data set serving as basis to derive blue prints for the reproduction of the instrument or parts of it (e.g. to produce spare parts).
- Analysis of materials in the interior of the instrument or beneath covering layers. This issue affords high accuracy and reproducibility of the reconstructed material densities.
- Generation of 3D-images used for virtual exhibitions, educational reasons or 3D-printings of showcase replica.

Optimization of X-ray CT imaging is in progress as well as the specification of a meta-data format comprehensively describing the measurement procedure. Together with the meta-data format and the optimized measurement protocols, case studies, a check list and a guideline for transport and handling of the historical instruments will be part in the final best practice guide. As an example a violin made by Hummel (MI419), which was scanned with extended field of measurement, is shown in Fig. 1.

Figure 1: Cross section through a violin showing f-holes and corner blocks. The inset shows a magnification of the upper right corner. The voxels have an edge length of 44 µm. This allows e.g. for a dendrochronological examination of the wood.

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References