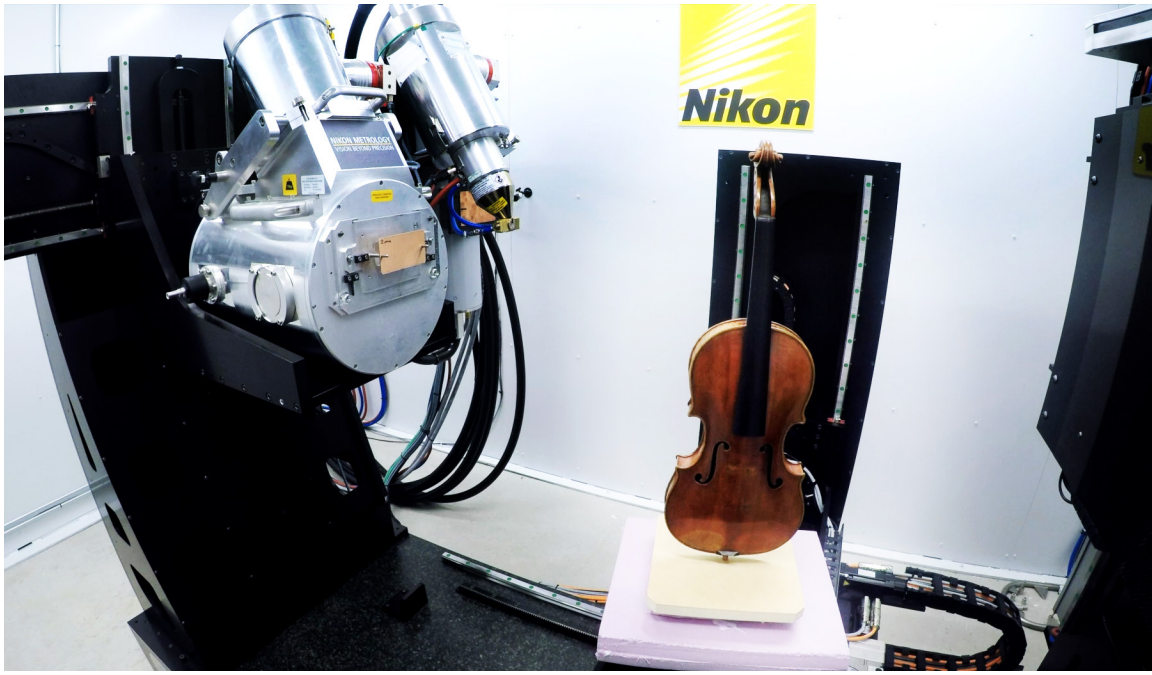
X-RAY CT SCANNING

The Sweet Sound of X-Ray CT Scanning

Nikon Metrology takes the measure of a 280-year-old violin



An 18th-Century Venetian violin being scanned by Nikon Metrology's large envelope M2 micro focus X-ray/CT inspection system.

"What's past," as William Shakespeare wrote in The Tempest, "is prologue." Which means that the people, the events, and even the musical instruments of yesteryear form the prism through which we view the world of today.

That's an assessment of history with which the board members of the Oberlin Violin Makers Foundation would certainly agree. Their mission is to promote and preserve the rich lineage of violin making, an art (as well as a science) that stretches back to Italy in the late Renaissance. One way they accomplish this goal is through the careful modeling and reconstruction of extremely rare antique violins.

"Each year we choose a project in which we copy, study, and learn from a classic violin—mostly Italian-made, from the early 1600s to mid-1700s," says Raymond Schryer, vice president of the Oberlin Violin Makers Foundation. "Our most recent project was a Domenico Montagnana instrument from 1739 loaned to us from a private collector. The style is very different from a Stradivarius or a Guarneri… it has higher arching and the red varnish, typical for the Venetians of that period, is quite beautiful."

Given the value of the instruments with which they work, destructive means of precision analysis for the purposes of replicating a violin such as the 1739 Montagnana is obviously out of the question. Thus, X-ray computed tomography (CT) became the technology of choice for the members of the Oberlin Violin Makers Foundation in their mission to reverse-engineer and thereby discover how past masters created their instruments.

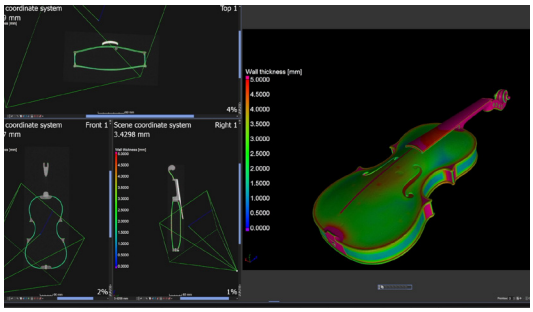
The science of measurement is informed by the past as well. The theoretical underpinnings of CT scanning, medical as well as industrial, trace back to the work of the Austrian mathematician Johann Radon more than a century ago. Radon's work, embodied in the transform that bears his name, permits the three-dimensional extrapolation of two-dimensional data. During the CT scanning process, that acquired data is reconstructed into a three-dimensional representation of the interior structure of the scanned object, whether it be the ribs of a human being or the ribs of an antique violin.

CT was initially applied in the early 1970s for use in the medical field, where the technology's additional dimension of information made it an important complement to traditional X-rays. Its use as an industrial tool for inspection dates to the 1980s; by 2005, when CT's resolution had reached that of individual X-rays, it was being investigated for its use as an important tool in dimensional metrology.

ART MEETS SCIENCE

When the Oberlin Violin Makers Foundation first decided to scan their violins a few years ago, they used medical CT technology. However, there were issues with this approach.

"Medical CT scanning is great because you have not just outside info, but inside info, too," says Schryer. "But the thickness of the slices of information was only about 0.3 mm. You need better resolution than that to 3D



A 3D color map of wall thickness and sectional analysis of the 18th-century violin CT scan data.

Members of the Oberlin Violin Makers Foundation and Nikon Metrology's X-ray/CT contract inspection services team prepare the antique violin for the non-destructive CT scanning and analysis process.

print a really accurate model from an STL file," which is a triangulated surface file showing both inner and outer surfaces.

That's where Nikon Metrology entered the picture.

"A colleague had purchased a small scanner from Nikon Metrology to do their research," Schryer recalls. "That's how I learned of the quality of the scans with high-resolution CT Imaging compared to medical CT scanners."

Schryer and five other members of the Oberlin Violin Makers Foundation traveled to Nikon Metrology's facility in Brighton, Michigan, to analyze the violin. It was scanned by Nikon Metrology's M2 high-precision X-ray/CT inspection system, using a 225kV microfocus source. This powerful scanner provided almost three times the resolution that the Oberlin Violin Makers Foundation had been receiving from their medical scanners, translating to 5,453 slices of information vs. 1,829. That level of detail is imperative when you are attempting to replicate an object in which every micron of material makes a difference in the performance.

"This was a successful data acquisition for our violin research. We certainly hope to acquire scans like this on a yearly basis, we look forward to working with the Nikon Metrology group again."

Raymond Schryer,
vice president of the Oberlin Violin Makers Foundation

"To achieve the highest resolution possible for a sample that is this long, we used a scanning method called 'X.tend' or 'Helical CT Scanning,'" says Fabio Primo Visentin, with Nikon Metrology's contract inspection services X-ray/CT team. "This is a big deal because most other systems cannot fit a part of this size to CT scan, let alone scan it by using the Helical CT Scanning method." This allowed the Nikon Metrology team to gather data on the violin in one long scan.

"The violin started below the detector and rotated slowly as it moved through the beam and finished above the detector," says Andrew Ramsey, Nikon Metrology X-ray/CT consultant. "We had to specially shorten the height of the detector to cope with the full two feet of the violin height, but this will be a very useful feature for scanning other tall specimens. For narrower specimens scanned at higher magnification we can scan even taller samples but as the samples get wider and require lower magnification the height of sample we can scan becomes more limited."

THE MICRO CT DIFFERENCE

The difference in accuracy between medical CT and Nikon Metrology's micro CT is quite simple: It all comes down to a smaller, more powerful X-ray spot, which equates to better resolution. Thus, for industrial applications in which the visibility of the inside contours and dimension of a part at the highest possible resolutions is essential, micro CT is the technology of choice.

"Our helical method uses a taller pitch, meaning the height between the turns of the helix, than most other scanners," says Ramsey. "That means we can scan the samples more quickly. The reconstruction algorithm, the first exact helical cone-beam algorithm developed in 2003, allows us to use this large pitch but means that the precision of our sample manipulator must be extra high. The algorithm produces a 3D grayscale CT volume where each point in the 3D dataset represents the X-ray absorption at that point. Clever algorithms in the analysis software we use (VolumeGraphics' VGStudio MAX software) determine the surfaces within the volume, triangulate them into millions of little triangles, and then export these as an STL file, which is viewed and measured in the 3D RhinoCAM software."

"The process at the Nikon Metrology facility in Brighton was fantastic," Schryer says. "They spent adequate time to show us (there were six of us violin makers from the Oberlin group) the process of scanning."

The resulting digital information was the most important output of the project.

"Ours is the world's best violin makers' archives for scans and data," says Schryer, proudly.

From this data, the various component parts of the violin, such as the ribs, the scroll, the neck, and the rest of the body of the instrument, are 3D printed and re-assembled into a workbench copy of the instrument for study by the masters at the Oberlin Violin Makers Foundation. They will then painstakingly re-create (over the course of two years) what will be, for all intentions and purposes, a replica of the Montagnana original.

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After each Oberlin Violin Makers Foundation project is completed, the replica violin is sold to an eager market of musicians and collectors. The proceeds help fund the group's ongoing work, which ensures that this process, which began far in the past, will continue well into the future.

So, you see, what's past is not only prologue; sometimes, with the help of cutting-edge technology, it's epilogue as well.

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