How to learn about a world-class double bass? Give it a CT

July 3 2024, by Darcy Lewis

The instrument imaging team, from left: Philadelphia Orchestra bassist Duane Rosengard; Peter Noël, PhD, director of CT Research at the Perelman School of Medicine; luthier Zachary S. Martin; Leening Liu, a PhD student in Noël's Laboratory of Advanced Computed Tomography Imaging; and Mark Kindig. Credit: University of Pennsylvania

When you're an expert in medical CT imaging, two things are bound to happen, says Peter Noël, Ph.D., associate professor of Radiology and director of CT Research at the Perelman School of Medicine. One: You develop an insatiable curiosity about the inner workings of all kinds of objects, including those unrelated to your research. And two: Both colleagues and complete strangers will ask for your help in imaging a wide variety of unexpected items.

Over the course of his career, in between managing his own research projects, Noël has imaged diverse objects ranging from animal skulls to tree samples from a German forest, all in the name of furthering scientific knowledge. But none has intrigued him as much as his current extracurricular project: the first known attempt to perform CT imaging of some of the world's finest string basses.

The goal is to crack the code on what makes a world-class instrument. This knowledge could both increase the ability to better care for masterworks built between the 17th and 19th centuries, as well as providing insights into refining the building of new ones, including possibly shifting from older, scarcer European wood to the use of sustainably harvested U.S. wood.

That's why Noël and Leening Liu, a Ph.D. student in Noël's Laboratory of Advanced Computed Tomography Imaging, have found themselves volunteering to run the basses through a Penn CT scanner occasionally, when they're not developing next-generation CT technology.

"We always learn something out of projects like this … the more appealing part is that medical research can also be applied to non-medical things," Noël said. "We have the opportunity to take what we learn in medicine and use it for something else—in this case, moving the arts forward."

All about that bass

The project was born out of a partnership among Philadelphia bassist and independent scholar Duane Rosengard, a member of the Philadelphia Orchestra since 1986, who has authored several books on stringed instruments from the 16th century to the present; along with his childhood friend and amateur bassist Mark Kindig of Maryland; and long-time collaborator and award-winning luthier Zachary S. Martin of Rhode Island.

To grasp the project's potential scholarly and artistic importance, it helps to understand a bit about the bass itself. Taller and wider than most people, the bass's sonorous tones create an aural anchor whenever and wherever it's played, ranging from classical to jazz, rockabilly, bluegrass, and beyond.

"The double bass is the only stringed instrument that's used in virtually all genres of music around the world," Rosengard said. "With the bass, we often use descriptor words like organ-like, chocolatey, or velvety to describe the sound. We'd like to understand more of the 'why' of that."

Developed in the late 16th century, the bass exists today as a delightfully nonconformist instrument of which none of the dimensions—or even its basic shape—are fully standardized. This is in marked contrast with the violin, whose size, shape, and other specs have been established since about 1560, said Martin, who drives down from his workshop to prepare each bass for scanning. As a luthier, the term for craftspeople who build and restore stringed instruments, Martin has restored many fine old basses, some as old as 400 years.

Not only do violins share consistent dimensions, but also more is known about their internal characteristics. Their small size—with a body length of just 14 inches—has lent itself to scientific exploration via X-ray and

CT scanning for the past generation. With a violin, anyone in any imaging department can scan it easily, Noël said.

"Medical CT scanners are designed for human bodies, typically ranging from 40 to 50 cm in diameter," he said. "However, unlike the human body, basses are filled with air and often exceed 70 cm in diameter, presenting significant technical challenges that need to be worked out."

The connection with Penn came about through Siemens Healthineers, a leading manufacturer of CT machines and other medical equipment. After several requests at institutions throughout the country, Kindig and Rosengard finally connected with Noël, a music lover and Philadelphia Orchestra patron.

"It's quite extraordinary that after all of our searching throughout the country to find a big enough scanner, we connected with Penn Medicine, less than a mile from the orchestra's home at the Kimmel Center for the Performing Arts," Rosengard said.

Rosengard, Kindig, and Martin have assembled a wish list of some 20 of the world's finest old basses to examine with their Penn partners.

A complicated process

When a patient—or object—undergoes a CT scan, they lie on a bed that slowly moves through a gantry while an X-ray tube rotates around them, aiming X-rays through the body. CT scanners use special digital X-ray detectors. As the X-rays leave the patient, they are picked up by the detectors and transmitted to a computer.

Preparing a bass for a scan poses more challenges than the average patient. First, the bass requires a special bass holder, which Martin designed and made to cradle the instrument securely on the scanner.

Then, because any metal on the bass would severely distort the CT images, Martin and Rosengard, working in a backstage room at the Kimmel Center, remove all metal items including strings and tuning machines.

The most nerve-wracking part is taking off the strings; the sound post, a crucial cylinder of wood wedged between the instrument's front and back at the bridge, can collapse without pressure from the strings.

Ever-meticulous, Martin photographs and numbers each screw that comes out of an instrument's tuning machines. They're stored in the locked room while the bass is at Penn. Once the scan is complete, Martin and Rosengard return to the Kimmel Center and reverse the process, Martin making any minute adjustments needed to ensure the bass is exactly as it was before the scan.

The team has set its focus on exploring two data points for each bass: internal air volume and the density of its wood. "We believe the air volume has everything to do with why a bass sounds the way it does, because it directly relates to the sonority of a particular instrument and its presence or power," Martin said. "And wood density very much plays into the instrument's structure, flexibility, and responsiveness."

The medical connection

Liu operates the scanner when Rosengard and Martin bring in one of their rare basses. She also helps calculate the instruments' internal volumes. "From the internal corpus volume perspective, it's a straightforward calculation for us," she said. "It means segmentation, counting the pixels, and then using the pixel volume to calculate how much volume is within the bass itself."

As for mapping the density of the wood, this issue is more relevant to

Liu's Ph.D. research than you might expect. Her thesis focuses on using physical density to measure temperatures within the human body, specifically for thermal ablation, a minimally invasive treatment for cancers, including those of the liver and kidney. Carefully directed high temperatures are used to kill both tumor cells and a surrounding safety margin of healthy tissue, and knowing the temperature at which the tissue is burned gives an idea of the treatment's effectiveness.

So far at least, the wood density component is the more challenging scientifically, Liu said.

"In the temperature project, the scanner outputs quantitative maps that we can use to successfully generate physical density maps," she explained. "We were hoping that translating that for the bass would also be possible, but there are still some challenges with that approach we're trying to resolve."

Challenges aside, these collaborators from both creative and quantitative disciplines are delighted to be working together.

"We scientists love to talk about the science part and the musicians feel the same way about music," Noël said. "We all have a common sense of what we want to achieve, but it's inspiring and amazing to see what happens when two totally different worlds talk to each other."

Provided by University of Pennsylvania

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