MicroCT

Our theme for this issue of Quest is micro-computed tomography, known as microCT or just µCT

What is microCT?

MicroCT is a 3D imaging technique utilising X-rays to see inside an object, slice by slice. MicroCT, also called microtomography or micro-computed tomography, is similar to hospital CT or 'CAT' scan imaging but on a small scale with greatly increased resolution. Samples can be imaged with pixel sizes as small as 100 nanometres and objects can be scanned as large as 200 millimetres in diameter.

MicroCT scanners capture a series of 2D planar X-ray images and reconstruct the data into 2D cross-sectional slices. These slices can be further processed into 3D models and even printed as 3D physical objects for analysis. With 2D X-ray systems you can see through an object, but with the power of 3D microCT systems you can see inside the object and reveal its internal features. It provides volumetric information about the microstructure, non-destructively.

How does a microCT scanner work?

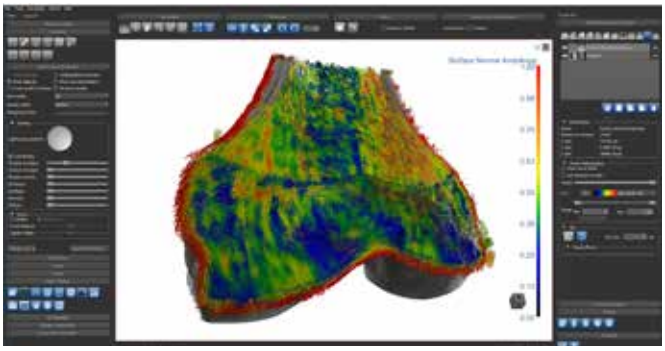
X-rays are generated in an X-ray source, transmitted through the sample, and recorded by the X-ray detector as a 2D projection image. The sample is then rotated a fraction of a degree on the rotational stage, and another X-ray projection image is taken. This step is repeated through a 180° turn (or sometimes 360°, depending on sample type). The series of X-ray projection images is then computed into cross-sectional images through the computational process called 'reconstruction'. These slices can be analysed, further processed into 3D models, made into movies, printed into 3D physical objects, etc.

What does non-destructive testing mean?

Non-destructive testing means that the sample or specimen being scanned isn't altered or destroyed during testing, or in the preparation for testing. This allows the sample to be preserved for historical record, tested again at a later date, used in another test or put into final production. Some other techniques require staining, cutting or coating of samples, which can affect the sample's structure, its ongoing usefulness, or its use in later studies. There are several techniques that allow samples to be imaged in their native states, including light microscopy, laser scanning, visible and other spectrum photography. MicroCT is one such technique where most of the samples studied are scanned in an unaltered state.

Indaba yethu kulesisqephu igxile kwi computer encane yokuthatha ezithombe emzimbeni, ibuye yaziwe ngokuthi I microCT noma µCT. Lona ngumshini okwazi ukukhipha izithombe zamathambo noma izicubu zomzimba, usebenzisa imisebe evela macala onke ento ayishuthayo ukuze kuphume izithombe ezi two-dimensional (2D), bese zihlanganiswa ukukhanda I three-dimensional (3D).

Translation by Zamantimande Kunene



Following microCT scanning, the image data can be processed for detailed analysis. *© Dragonfly ORS, Wikimedia*

What are the advantages of microCT scanning?

MicroCT provides high-resolution 3D imaging information that can't be obtained by any other non-destructive technology. It can be used to study the interior structure of both material and biological samples without having to cut the samples, preserving the samples or specimens for future studies. The quantitative information obtained from microCT scanning can only be obtained from 3D images, and 3D digital models created from microCT virtual slices allow scientists to measure any parameters for comparison in before-and-after studies.

These unique features of microCT scanning allow scientists to look at the morphology of a sample and study features such as porosity, structure / bone thickness, volume fraction, defect analysis, density, particle size, voids and fibre orientation. Researchers use microCT to study bone, teeth, tissue / organs, composite materials, medical devices, batteries, etc.

What is the difference between medical CT and microCT scans?

MicroCT scanning is X-ray imaging in 3D, using the same method as medical CT (or 'CAT') scans, but microCT is on a much smaller scale with greatly increased resolution. Scans from medical CT – introduced as a tool for medical imaging in the 1970s – are limited to a resolution of one millimetre, which provides sufficient detail for clinical use. For materials science and small animal imaging, much higher resolution was needed, so microCT scanning was introduced in the 1980s. MicroCT scanners can work at the level of one micrometre (or micron), which is a thousandth of a millimetre, and smaller.

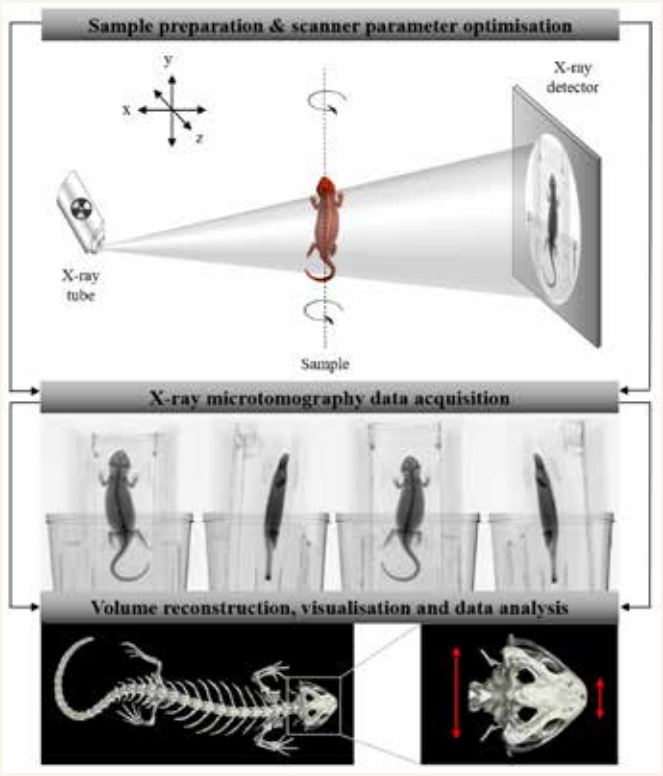
What is the difference between *in vivo* and *ex vivo* microCT scanning?

Simply put, *in vivo* (Latin for *within life*) is the scanning of live specimens and *ex vivo* (Latin for *out of living*) typically refers to things that used to be alive or samples excised from something that had been alive. For microCT, *in vivo* typically refers to systems that scan mice and rats and in some cases rabbits, while *ex vivo* systems typically handle the remainder of the applications.

With *in vivo* microCT instruments, since the animal remains alive, longitudinal studies can be performed to measure the effects of drug, diet, hormonal and other treatments on tumours; bone growth and quality; body mass and other applications on the same subject. This can reduce the number of animals needed for a study.

Ex vivo microCT instruments typically handle the remaining applications, which include end-point studies of specific regions of an animal that get excised (lungs, bone, tumours, implants, grafts, etc.), biomaterial studies, implants in large animals, materials studies, compression studies, and more. *Ex vivo* microCT instruments allow for higher spatial resolution, longer scan times (since dose to the sample isn't of concern), better signal to noise ratios, and therefore better images. *Ex vivo* systems have typically been used for most applications outside of a living animal.

The word tomography is derived from the Greek word 'tomos', meaning slice or section, and 'graphe' meaning drawing.



https://doi.org/10.1163/15685381-20181102

Above: Schematic of the microCT scanning and data-processing technique. *© Broekhoven and Du Plessis*

Below: This live armadillo lizard entered defensive mode, with typical tail-biting behaviour, prior to the cooling stage and maintained this 'pose' throughout the scanning period. The 3D-rendered image shows the arrangement of the bony plates, called osteoderms, embedded in the skin after digitally removing the scales. *© Broekhoven and Du Plessis*

https://doi.org/10.1111/2041-210X.12661

Close Encounters of the **3D** Kind

Live animals usually need to be anaesthetised, either via injection or inhalation, prior to microCT scanning to ensure they keep perfectly still during the process, because any movement would result in blurry images. Chris Broeckhoven and co-researchers at Stellenbosch University recently described a protocol to immobilise and restrain live reptiles and amphibians without administering anaesthetic. These 'cold blooded' animals – more correctly known as ectotherms – cannot produce internal heat to maintain their body temperature, so if they become cold they quickly enter a state of torpor (chill coma).

The researchers used live lizards as their example to explain the protocol. Each lizard was restrained between two taped-together Styrofoam blocks, and then placed in a holder with crushed ice in a way that ensured no part of the animal came into contact with ice or meltwater. This cooled the specimen to a chilly 8°C before scanning began. Experiments were conducted with various scan settings to determine the effect on radiation dose rate, image quality and scan time. Apart from some blurriness in images of the sides of the thorax due to the lizards' breathing, the results were comparable with microCT scans of dead lizards. After the scanning procedure, which took up to 16 minutes per individual, the lizards were monitored for a month in the laboratory, but no ill effects of the irradiation were apparent. The lizards were then released back into their natural habitat, and monitored for another three months using remote camera traps. Most of the lizards were recovered at the end of this period, and the researchers felt it likely that all the lizards were still alive at that point. But what an experience they had had – rather like the classic alien-abduction movie *Close Encounters of the Third Kind!*