D35 Data Integrity Issues for Micro-Computed X-Ray Tomography (μ-CT) in Forensic Applications

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After attending this presentation, attendees will understand the different artifacts that can influence μ-CT issues and metrological issues that affect the data.

This presentation will impact the forensic science community by creating greater awareness of the issues that need to be taken into account when presenting μ-CT data.

X-ray computed tomography has been widely used in forensic applications for a number of years, in particular as a means of performing virtual autopsies to determine cause of death. μ-CT has also been used to investigate tool marks on bones and for the analysis of the remains of Richard III. μ-CT has a number of advantages over traditional X-ray computed tomography; most notably, it offers greater resolution and magnification. There are a number of artifacts that can occur in CT including noise, beam hardening, scatter, helical, ring and metal artifacts. Some of these artifacts can be reduced by the use of filters and collimators. There are also important considerations for the accurate dimensional use of μ-CT; thus the recording of magnification and resolution and the metrology of measurements is critically important for accurate forensic use of this technique. Nevertheless, μ-CT does allow the measurement of internal dimensions in a way that is not accessible by other techniques.

In μ-CT, a beam of X-rays is generated and focused, usually into a cone-beam. This beam of X-rays travels through the sample and as it does so, the intensity of the X-rays is attenuated. Attenuation depends on the energy (frequency) of the X-ray radiation, the material's density, element number, and the length of penetration of X-rays through that material. X-rays unattenuated by the sample reach the detector. The intensity of these X-rays is registered by the detector and converted to a digital signal. The intensity of X-rays at a particular pixel forms the radiographic image. Many radiographs are taken as a sample is rotated through a small angle while exposed to the beam.

Laboratory μ-CTs use a "white" polychromatic beam to generate as many photons as possible to obtain statistically reliable images within a reasonable time, but this can lead to beam hardening artifacts. Beam hardening is manifested on an image as dark streaks. Beam hardening arises from lower energy photons being more readily attenuated than higher energy photons. This means that beam transmission is complex and not a simple exponential decay as seen with monochromatic X-ray beams. Filters and collimators can be used to reduce the effect of beam hardening artifacts; the range of available filters and collimators will be discussed in relationship to the analysis of gunshot residue.

The radiographs obtained in the μ-CT scanning are reconstructed by software to form a 3D volumetric model. The model consists of 3D voxels (volumetric pixels) of varying gray levels depending on the attenuation at that point. The gray values correspond to varying material properties. Detection of edges between two materials is achieved by interrogating gray level thresholds. Surface points are extracted from this by defining a sampling interval on the surface model. The surfaces can then be used for defining and analyzing sample dimensions and whether or not another material is present.

The magnification and resolution of μ-CT images depends on the relative distances between the source, the sample, and the detector. In practical terms, how close the sample can go to either the source or detector depends on its size because the sample must be rotated by 360˚ to form the volumetric 3D surface. The spatial resolution of μ-CT can be down to 1μm.

Metrology from measurements in μ-CT needs to be performed with care as the dimensional analysis of samples with known geometries shows that there are different relative errors in different analysis directions. The current understanding of the dimensional fidelity with respect to reference standards will be discussed.

The use of micro-computed tomography for investigation of a number of forensic issues will be considered, including measurement of tool marks on bone, detection of voids in welds, development of the internal structure of blow flies, and detection of metallic fragments from gunshot residue and Improvised Explosive Devices (IEDs). The use of phantoms for determining the composition of debris will also be illustrated.

Artifacts, μ-CT, Metrology