Generating 3D Image Data Using Micro CT

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Outline for this morning:

X-ray principles: production and detection
X-ray imaging: projection images
Computed tomography (CT) and micro CT
Kaffeepause
Image resolution
Micro CT applications and current work
X-rays are produced by interactions between fast electrons and matter.

A free electron passing within the electron cloud of an atom slows down and its lost energy is radiated as an x-ray photon.

Most of a source's output energy is in Bremsstrahlung, with relatively little in characteristic lines.

http://www.euronuclear.org/info/encyclopedia

http://www.3dx-ray.com/x-ray-scanning.html
An x-ray tube emits a spectrum of x-ray energies, limited by the anode voltage.

An x-ray tube generates radiation by drawing electrons from a hot cathode (K) onto a metal anode target (A) with a voltage \( U (=100 \text{ kV in this example}) \).

A microfocus source uses a transmission target and can produce a source spot size of a few microns or less.

http://www.euronuclear.org/info/encyclopedia

http://www.phoenix-xray.com
X-ray images can be made on photographic film or with a scintillator-coupled CCD camera

http://lifesciences.dalsa.com/technology/fiberoptics.asp
A normal medical x-ray (Röntgenbild) is a projection image.

Geometric magnification depends on the source-object-detector distances:

\[
\text{Mag} = \frac{\text{FOD}}{\text{FOD} + \text{FDD}}
\]
Image sharpness depends on spot size and on the source-object-detector distances

Image contrast depends on differential absorption of x-rays in the sample

Phase contrast is also possible with x-ray imaging and micro CT, but it works best for steep gradients

Pfeiffer et al. (2006)
Phase retrieval and differential phase-contrast imaging with low-brilliance X-ray sources
Nature Physics 2, 258 - 261
Micro CT works on the same principle as medical CT scans
CT reconstructs slices perpendicular to the axis of rotation.

Cone-beam CT makes all of the slice projections at once.

Tomography reconstructs a complete volume image from a series of projection images taken at many angles.

chick embryo, ca. 2 days, x-ray projection images
Reconstruction of the volume image is algorithmic: just a re-calculation of the projection image data.

chick embryo, ca. 2 days, rendered x-ray volume image
Tomography reconstructs a complete volume image with all internal points.

chick embryo, ca. 2 days, rendered x-ray volume image and two example slices