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X-ray microtomography

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Hello!

- Office B311 | haberthuer@ana.unibe.ch
- Master in Physics, then PhD in high resolution imaging of the lung at the Institute of Anatomy
- Post-Doc at the TOMCAT beamline of the Swiss Light Source at the Paul Scherrer Institute
- Post-Doc at the Institute of Anatomy in the µCT-group
  - Ruslan Hlushchuk, David Haberthür, Oleksiy-Zakhar Khoma, Fluri Wieland, Carlos Correa Shokiche
- Biomedical research
  - microangioCT [1]: Tumor vasculature, angiogenesis in the heart, musculature and bones
  - Cancer research: Melanoma
  - Lung imaging: Tumor detection and classification
  - Physiology: Zebrafish musculature and gills [2]
  - SkyScan 1172 & 1272

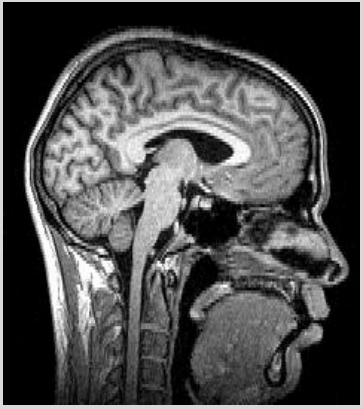
[1] **Hlushchuk2018**.

[2] **Messerli2019**.

Contents

Biomedical imaging

- Medical research



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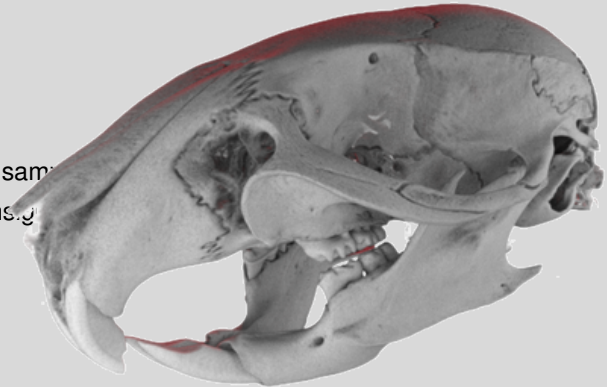
Biomedical imaging

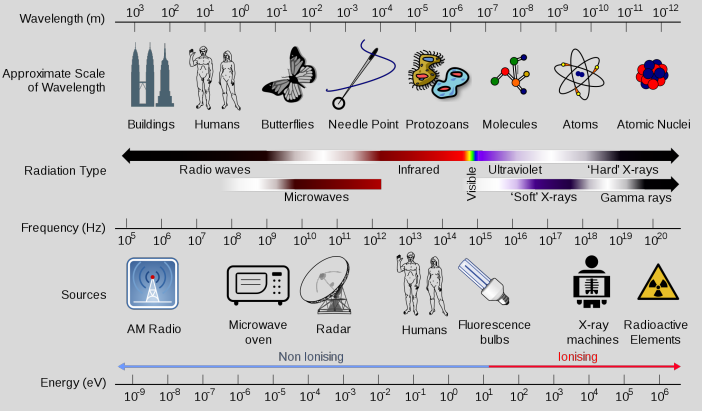
- Medical research
- (Small) Biological samples

Biomedical imaging

- Medical research
- (Small) Biological sam
- Non-destructive ins
  samples



Wavelength & Scale



w.wiki/7fz

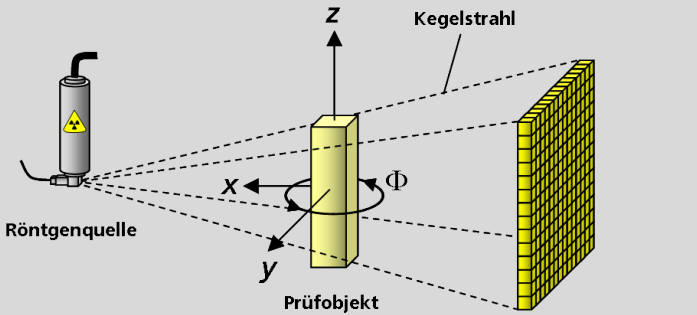
Imaging methods

- Light microscopy: see lecture of Nadia Mercader Huber
- X-ray imaging
- Electron microscopy: see lectures on Transmission Electron Microscopy by Dimitri Vanhecke, Scanning Electron Microscopy by Michael Stoffel and Cryoelectron Microscopy & Serial Block Face SEM by Ioan Iacovache.

CT-Scanner

youtu.be/2CWpZKuy-NE

What is happening?



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X-ray generation

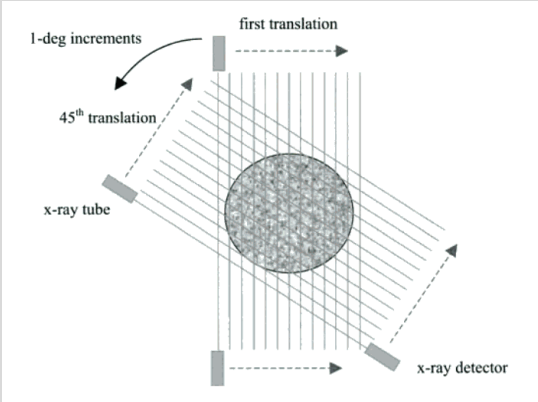
- How are x-rays generated
- Why do we need them

History

- Some history is found in [**Cormack1963**, **Hsieh2003**]

History

- Some history is found in [**Cormack1963**, **Hsieh2003**]
- First, second and third generation of scanners



From [**Hsieh2003**], Figure 1.12

History

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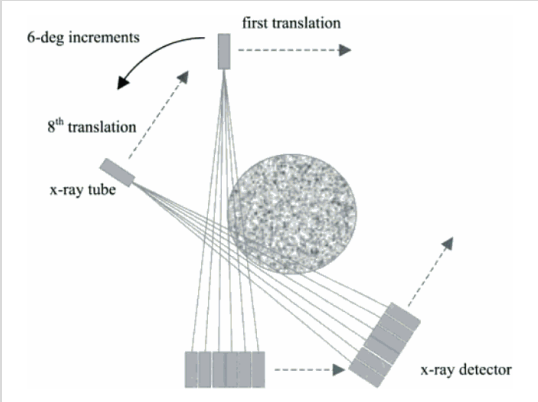

From [**Hsieh2003**], Figure 1.13

History

- Some history is found in [**Cormack1963**, **Hsieh2003**]
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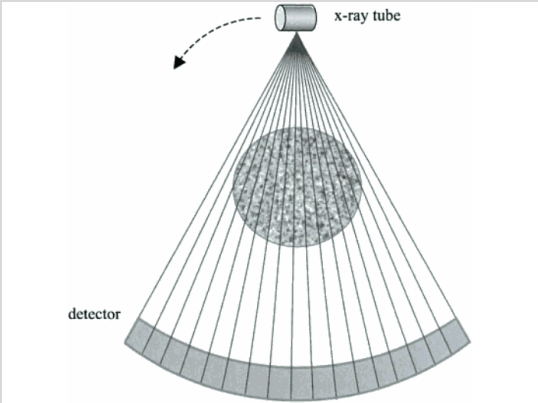


From [**Hsieh2003**], Figure 1.14

Machinery

- Hospital CT
  - Voxel size around 0.5 mm

flic.kr/p/D4rbom

Machinery

- Hospital CT
  - Voxel size around 0.5 mm
- Lab/Desktop CT
  - Voxel size around 7 µm (*in vivo*) or 0.5 µm (*ex vivo*)

flic.kr/p/fpTrGu

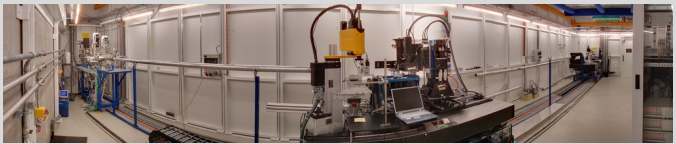
Machinery

- Hospital CT
  - Voxel size around 0.5 mm
- Lab/Desktop CT
  - Voxel size around 7 µm (*in vivo*) or 0.5 µm (*ex vivo*)

bruker.com/skyscan1272

Machinery

- Hospital CT
  - Voxel size around 0.5 mm
- Lab/Desktop CT
  - Voxel size around 7 µm (*in vivo*) or 0.5 µm (*ex vivo*)
- Synchrotron CT
  - Voxel size down to 160 nm



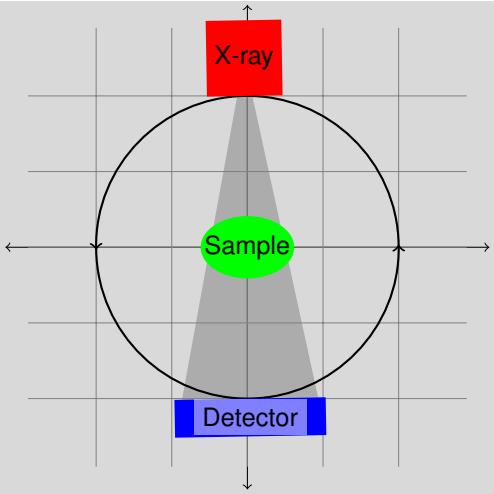
flic.kr/p/7Xhk2Y

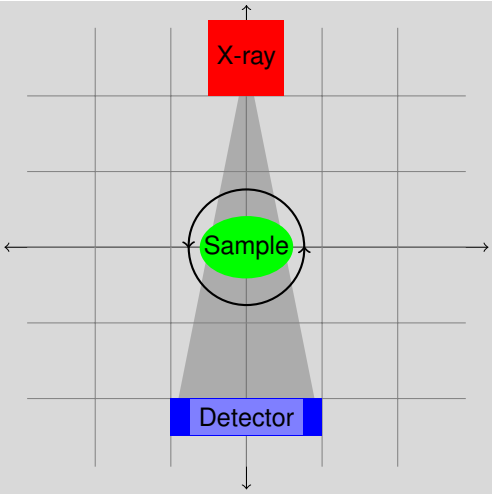
Machinery I

Independent on the machine, technically they are all a simple combination of

- an x-ray source
- a sample
- a detector

Machinery II

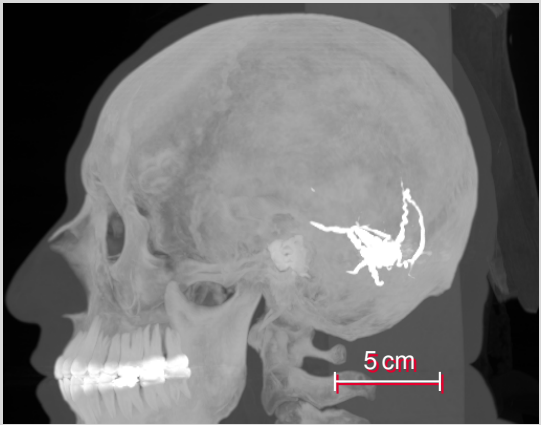




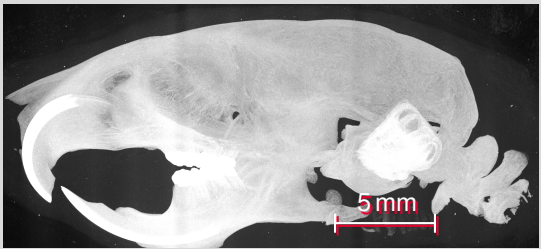
Preparation

- Study design
- Sample preparation

Why µCT?



From [**Clark2013**], Subject *C3L-02465*



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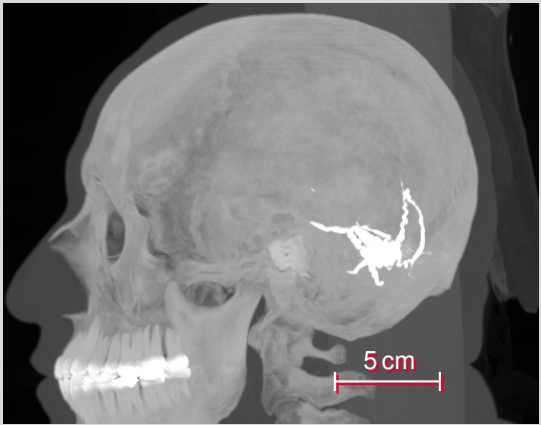

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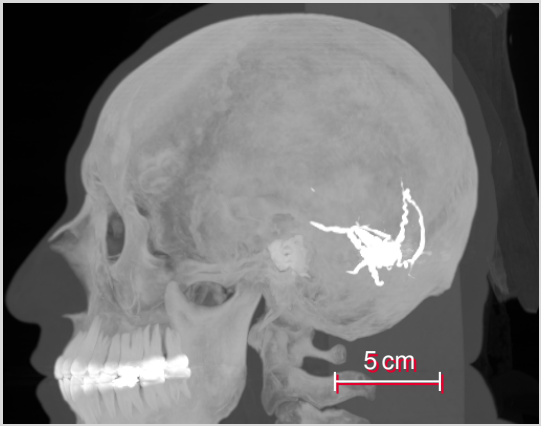

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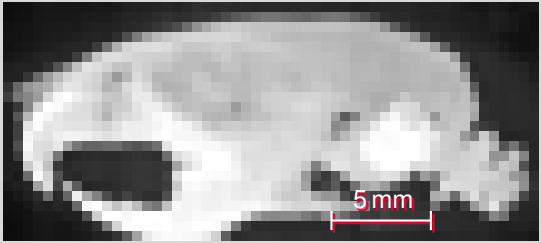

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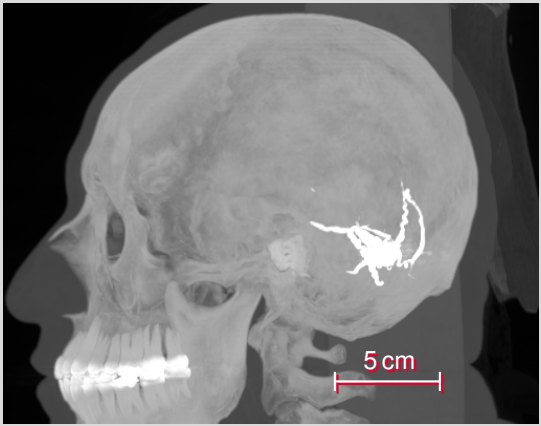

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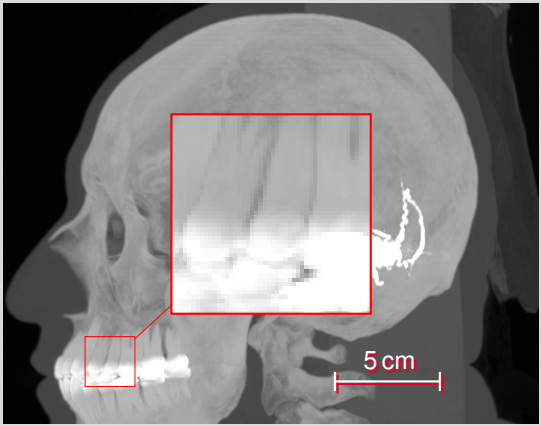

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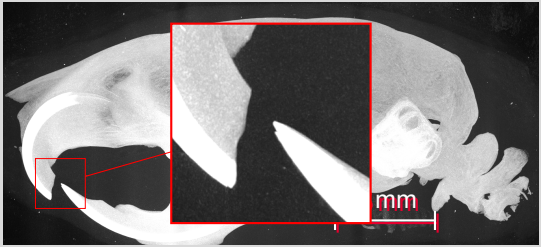
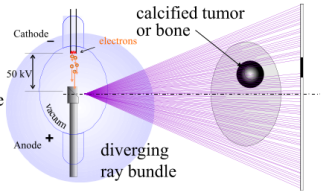


Projections

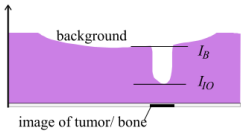
Image formation: shadow projection



X-ray tube:
nearly point like
photon source

Contrast is given by
absorption of intensity I
by object → negative

$$\text{Contrast} = \frac{I_{IO} - I_B}{I_B}$$



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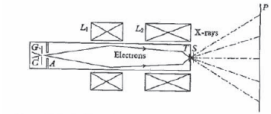
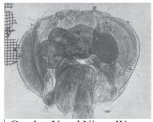
Laws of Physics for Microscopists by Michael Jaeger, Slide 14

Image formation: shadow projection

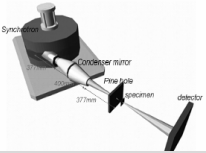
X-ray projection microscopy



Cosslett V E and Nixon W C X-ray Microscopy
Cambridge University Press 1960



Cosslett V and Nixon W
Nature 170 436–438 , 1952



Tabletop synchrotron
X-ray source Mirrorcle
2010

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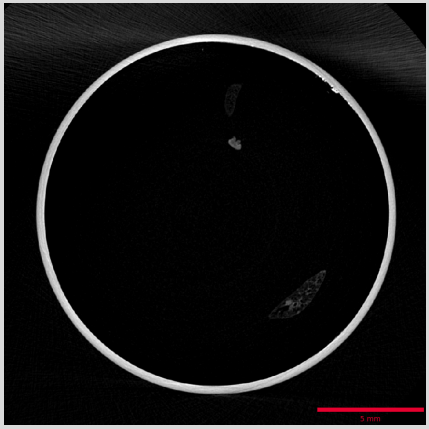
Laws of Physics for Microscopists by Michael Jaeger, Slide 15

Projections

Projections

- A (micro-focus) x-ray source illuminates the object
- A planar x-ray detector collects magnified projection images.
- What happens after penetration of the sample?
- Attenuation
- Conversion to visible light by Scintillator
- Detection, recording

Reconstructions



Reconstructions

- Based on hundreds of angular views acquired while the object rotates, a computer synthesizes a stack of virtual cross section slices through the object.
- Radon Transformation
- Filtered back projection
- Fan beam reconstruction
- Corrections (beam hardening, etc.)
- Writing to stack

Visualization

Visualization

- Based the on reconstructions, a computer synthesizes a three-dimensional view of the scanned sample

What to use?

- ImageJ [3]
-
- See *Fundamentals of Digital Image Processing* by Guillaume Witz

[3] **Schindelin2012**.

Quantitative data

- Raw numbers instead of just pretty images
- Segmentation
- Characterization

Big data

- TOMCAT 2560 px $\times$ 2160 px @ 1500 f/s, e. g. more than 8 GB/s
- Desktop µCT can easily produce more than 100 GB in a day

Reproducible research

- **git**
- Jupyter
- Script all your things!
- Data repositories → Sharing is caring!

Colophon

- This BEAMER presentation was crafted in LaTeX with the (slightly adapted) template from *Corporate Design und Vorlagen* of the University of Bern.
  - Full source code: git.io/fjpP7
  - The LaTeX code is automatically compiled with a GitHub action [4] to a PDF which you can access here: git.io/JeMjP
  - Spotted an error?
    Then please file an issue (git.io/fjpPb) or (even better) submit a pull request (git.io/fjpPN).

[4] Details on how this works are specified in a small test repository here: git.io/JeOOj

References