

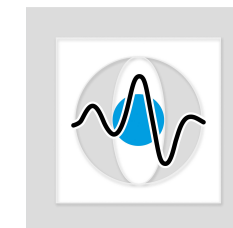
Medical Image Processing for Diagnostic Applications

Phantoms

Online Course – Unit 43

Andreas Maier, Joachim Hornegger, Markus Kowarschik, Frank Schebesch

Pattern Recognition Lab (CS 5)



Topics

Phantoms

Introduction

Numeric Phantoms

Physical Phantoms

Summary

Take Home Messages

Further Readings

Phantoms: Purpose

- The performance of reconstruction algorithms has to be evaluated.
- X-rays are ionizing → we cannot use patients.
- We do not know the exact “geometry” of patients.
- We need an object that is precisely known.

Phantom Types

We distinguish two kinds of phantoms:

Numeric/simulated phantoms ...

- ... originate from computer simulations.
- ... are known exactly.
- ... have only limited realism.

Real phantoms ...

- ... are designed with desired properties.
- ... are manufactured at a high accuracy.
- ... may be difficult to use.
- ... may still have a limited manufacturing accuracy.

Examples for Numeric Phantoms

Commonly used numeric phantoms:

- Shepp-Logan phantom
- FORBILD phantoms
- XCAT phantoms
- Many more custom made phantoms

Shepp-Logan Phantom

- Described by a series of additive ellipsoids
- Only available in 2-D (extensions in 3-D exists, but are not standardized)

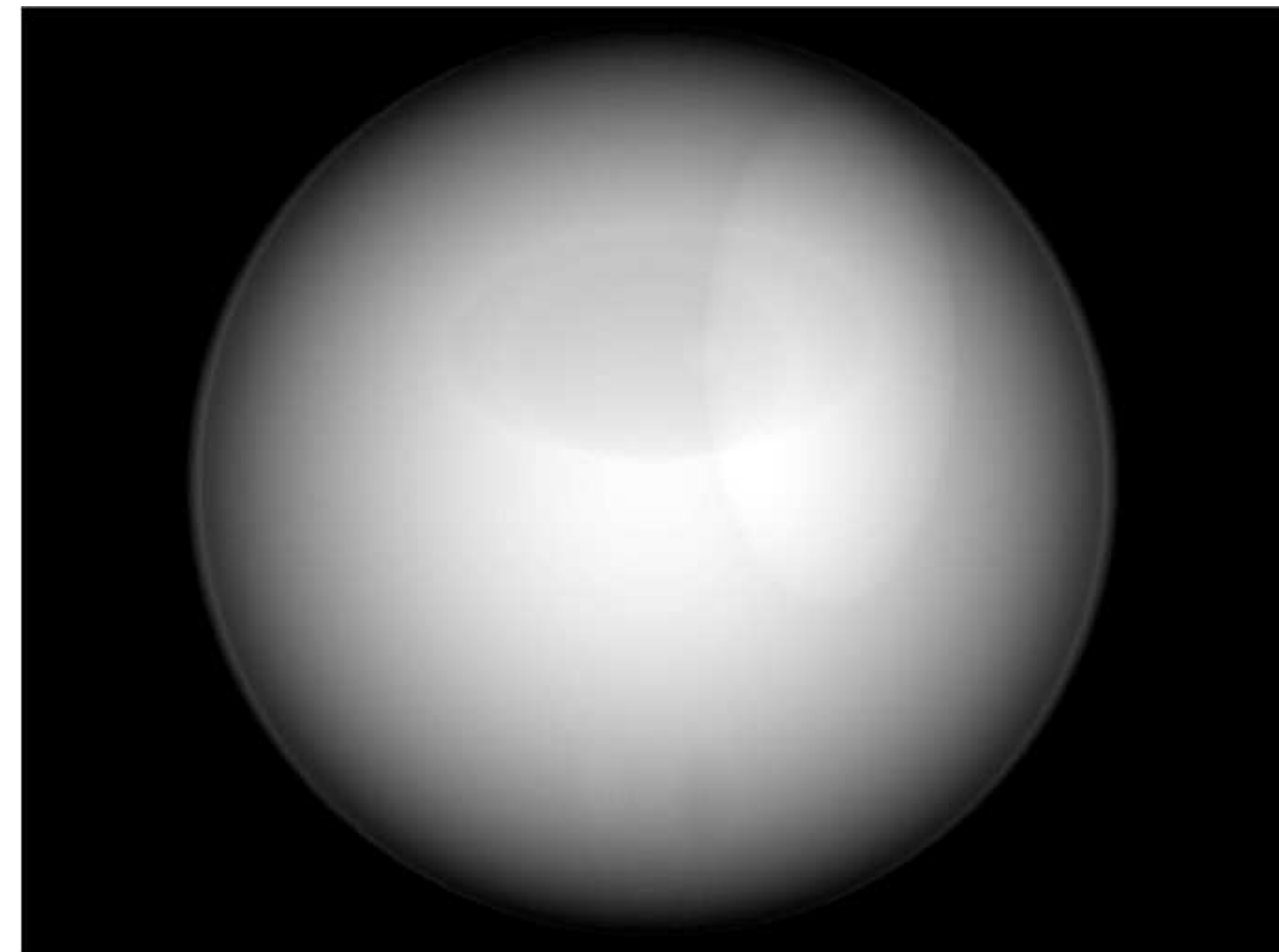
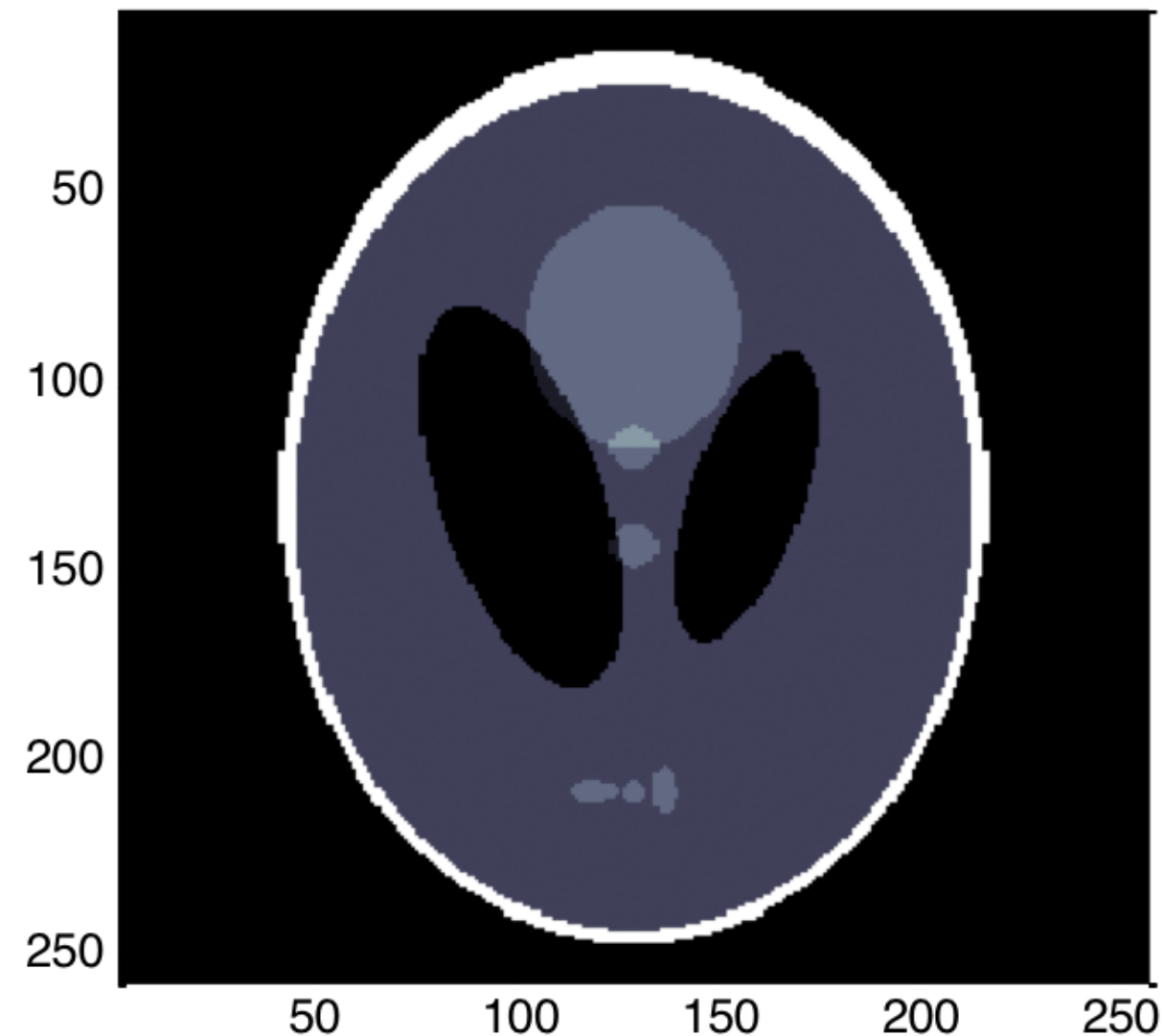


Figure 1: Shepp-Logan phantom in 2-D (left) and a 3-D version (right)

FORBILD Phantoms

- A series of 3-D phantoms that mimic anatomic details
- Descriptions based on simple geometric descriptors (cones, cubes, spheres, ...), and their intersections

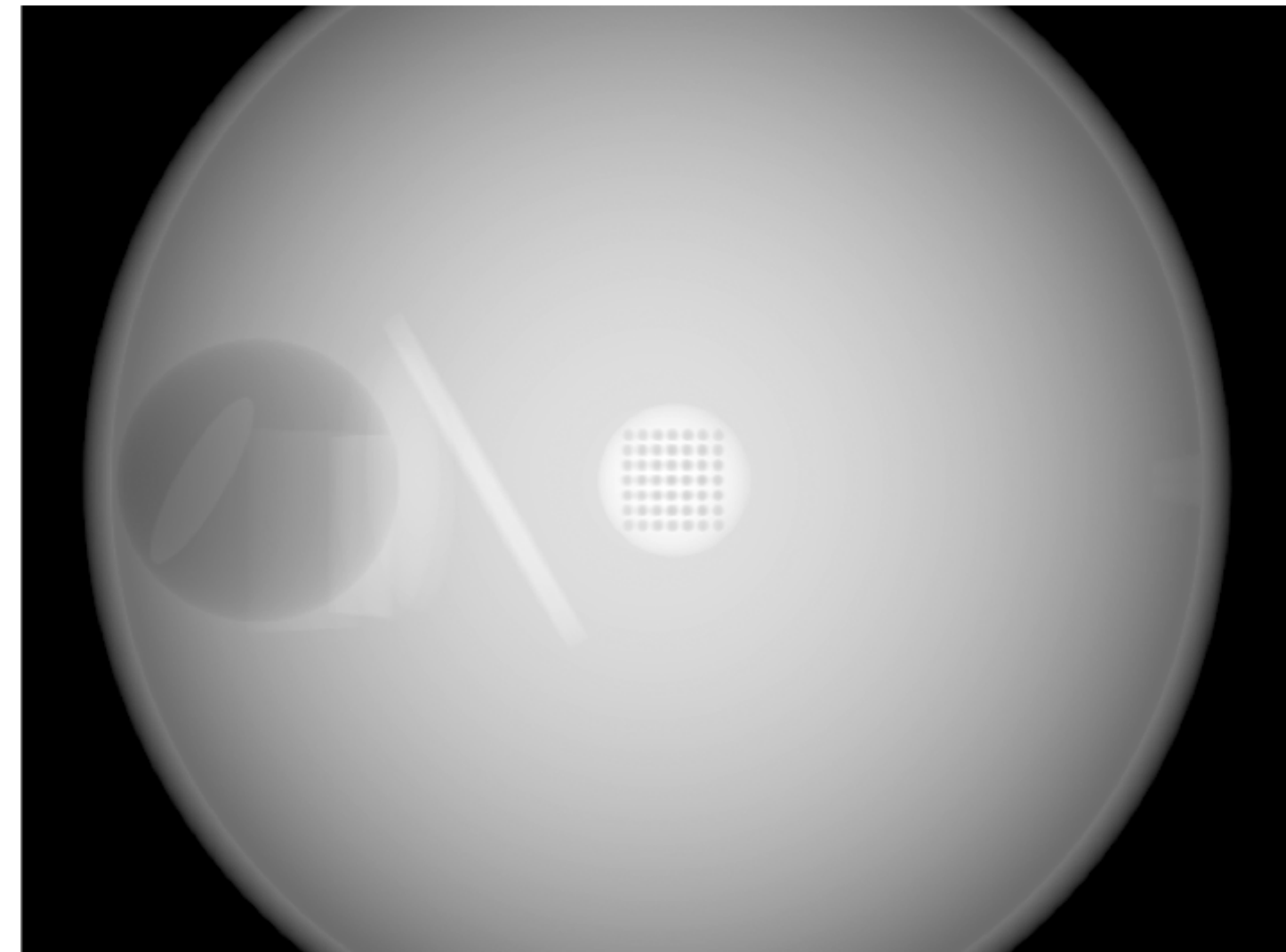
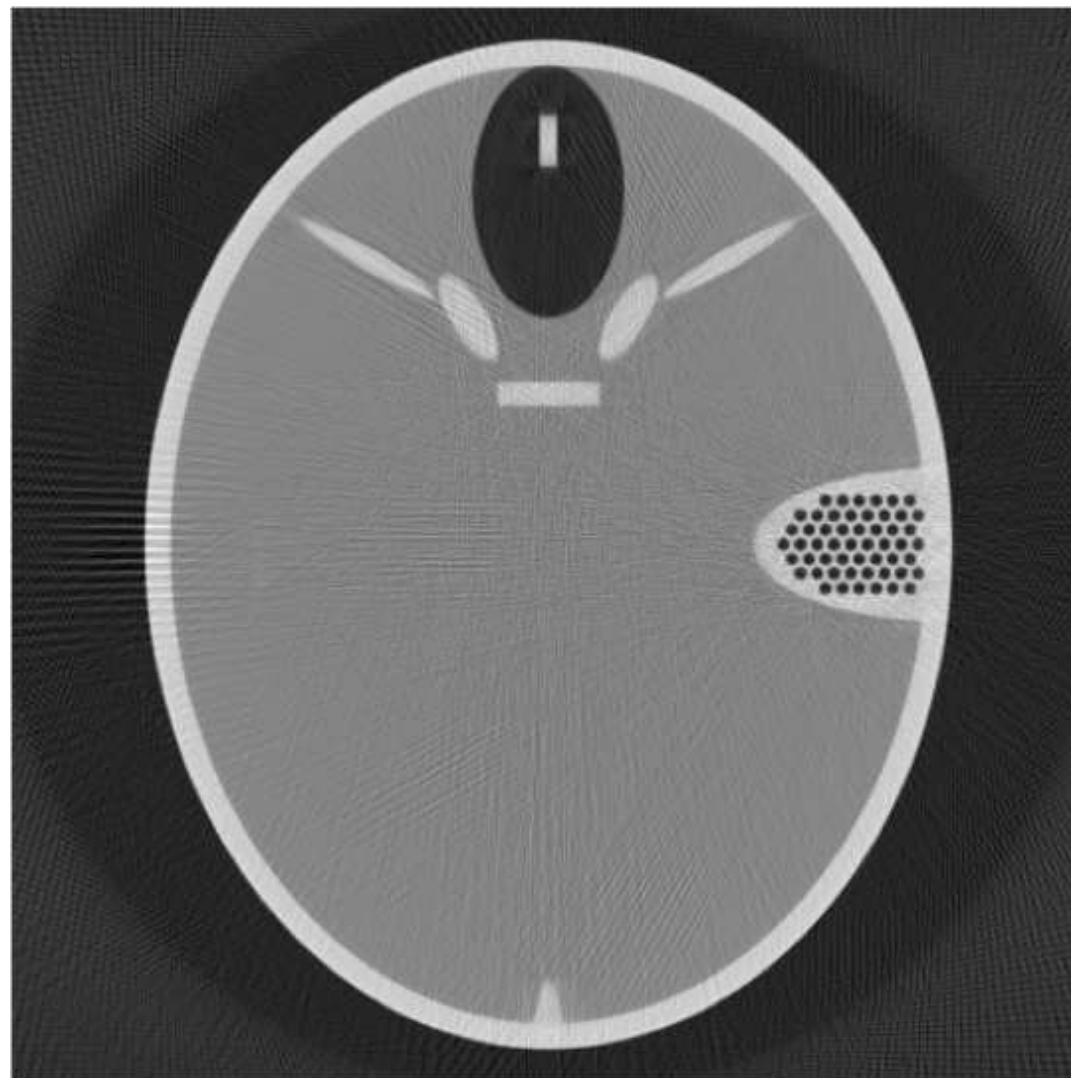


Figure 2: Examples for FORBILD phantoms

XCAT: Torso

- Based on the **Visible Human Project**®
- Analytic description using splines
- Comes with motion models for heart and torso



Figure 3: Beating heart in a breathing torso, link:
<https://www.youtube.com/v/Pbj0IFKh484>

XCAT: Heart

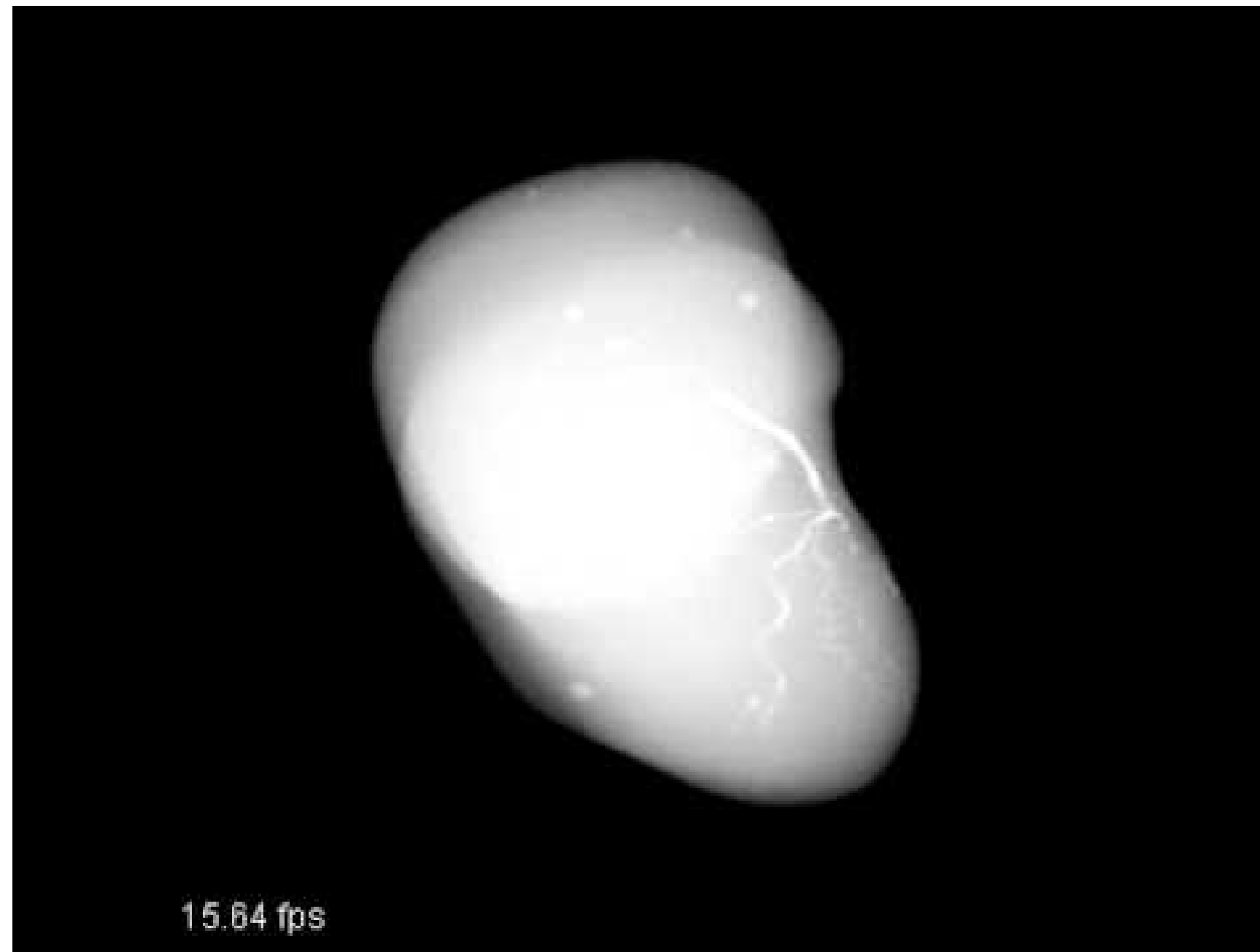


Figure 4: Beating heart with high contrast structures, link: <https://www.youtube.com/v/aQCHZCTbXBU>

XCAT: Legs

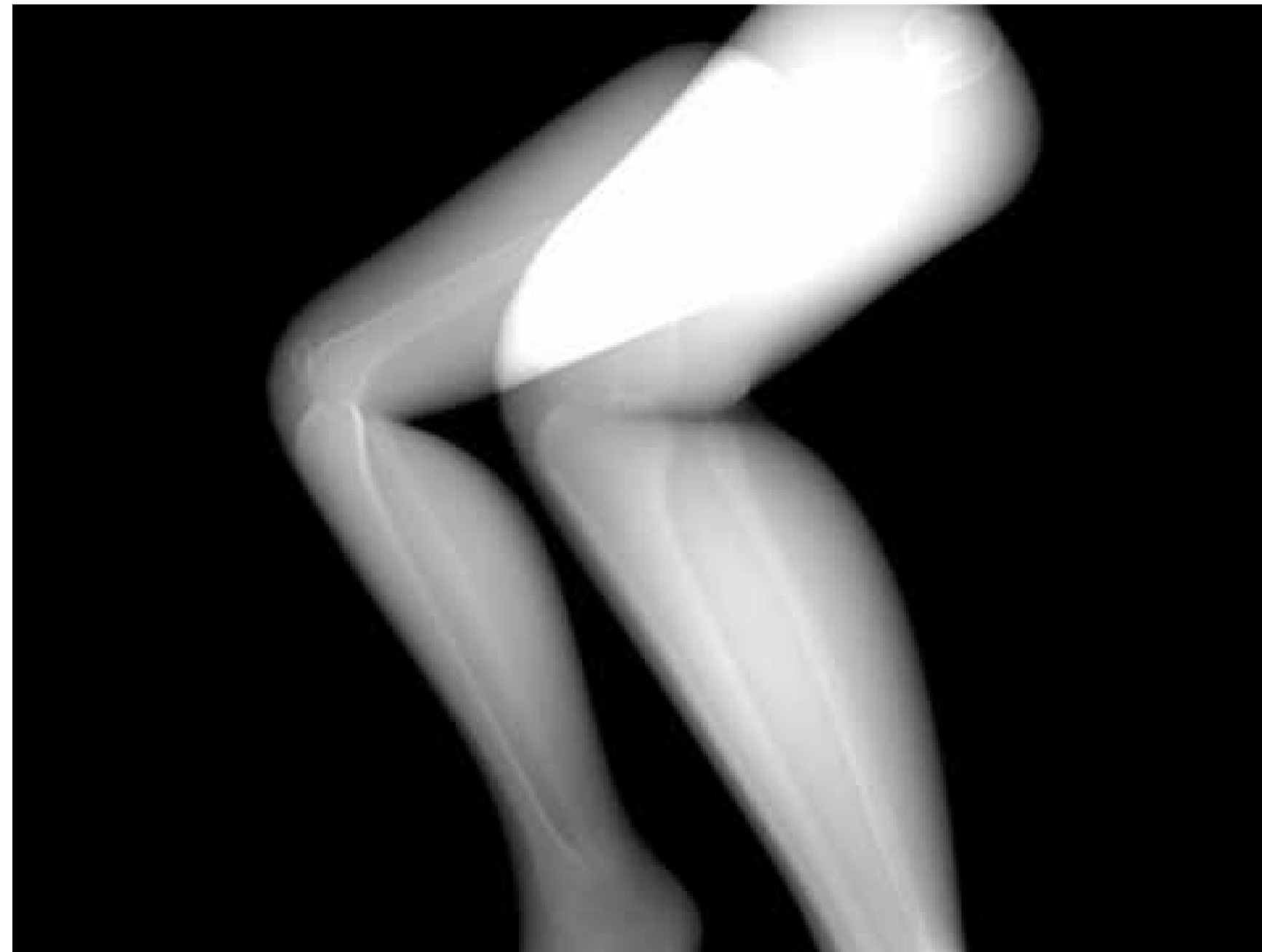


Figure 5: Squatting legs, link: <https://www.youtube.com/v/Dp-s6TeEUwo>

Examples for Physical Phantoms

Commonly used real phantoms:

- Catphan[®]
- ART phantom (earlier version: Alderson RANDO phantom)
- Calibration phantoms
- Many more custom made phantoms

Catphan®

- Phantom that mimics a water cylinder
- Contains exchangeable modules
- Manufactured at high accuracy

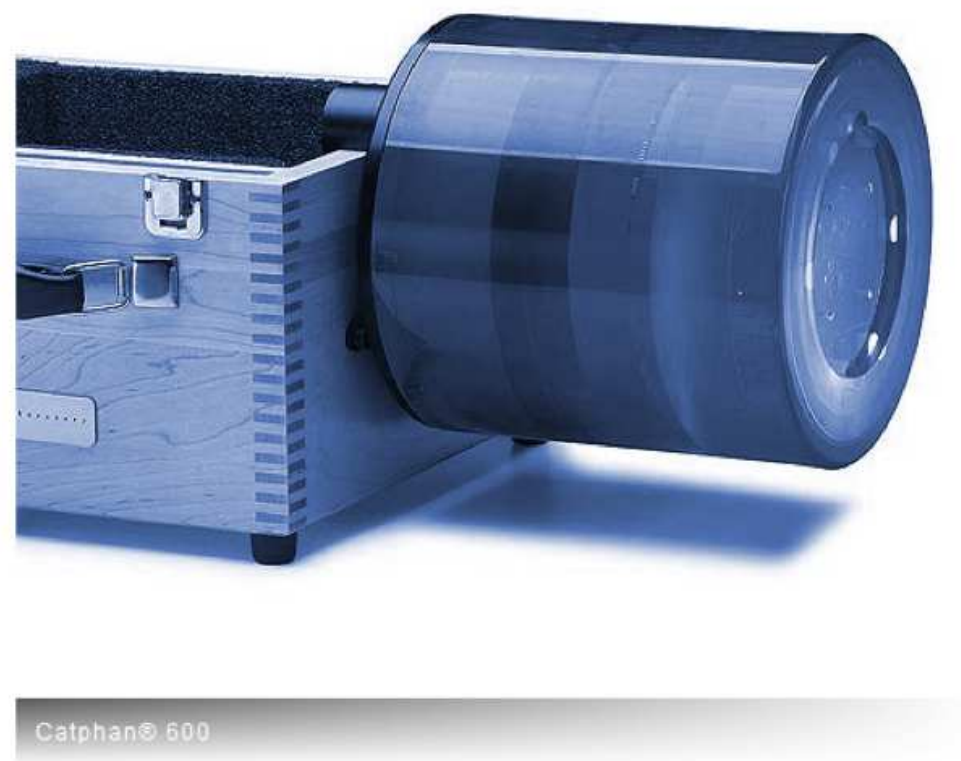


Figure 6: Catphan 600 (Image source: <https://www.phantomlab.com/>)

Alderson Radiation Therapy (ART) Phantom

- Phantom that mimics a human body
- Can be separated into slices
- Is also used to measure effective dose

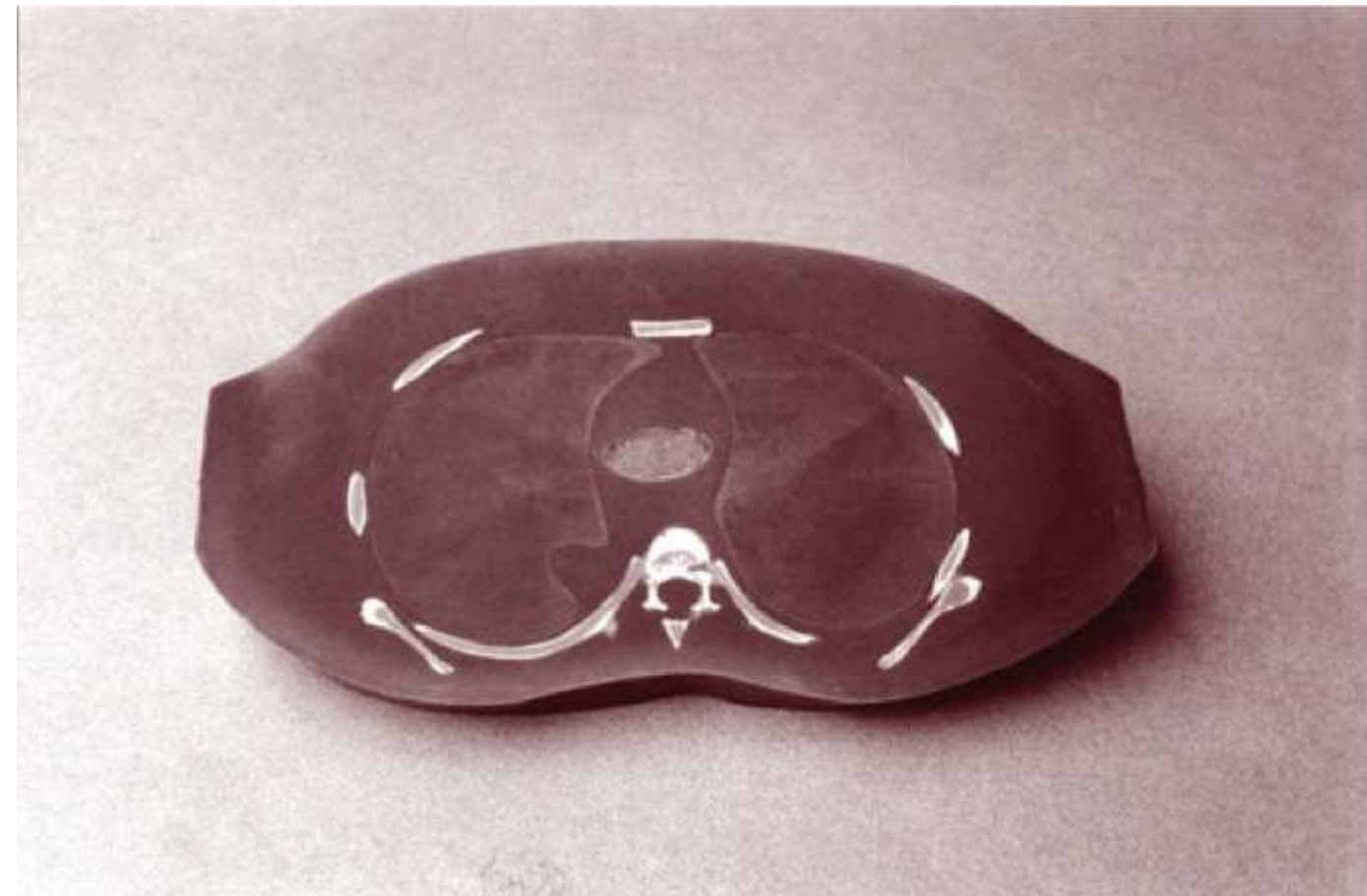
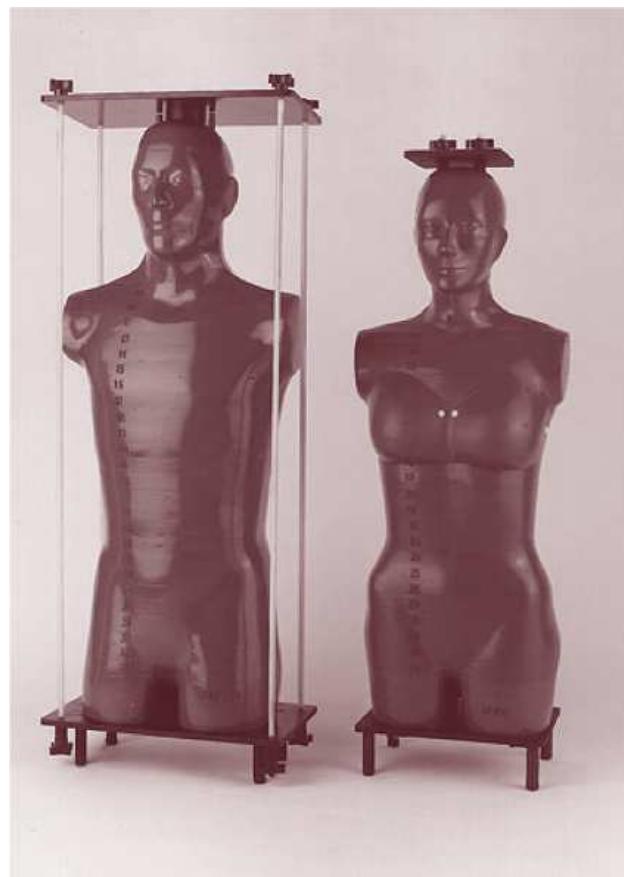


Figure 7: Male and female ART phantom (left) and a phantom slice (right) (Image source: http://rsdphantoms.com/rt_art.htm)

Calibration Phantoms

- Phantom that encodes information that can be used for calibration
- Enables to perform detailed accuracy analyses

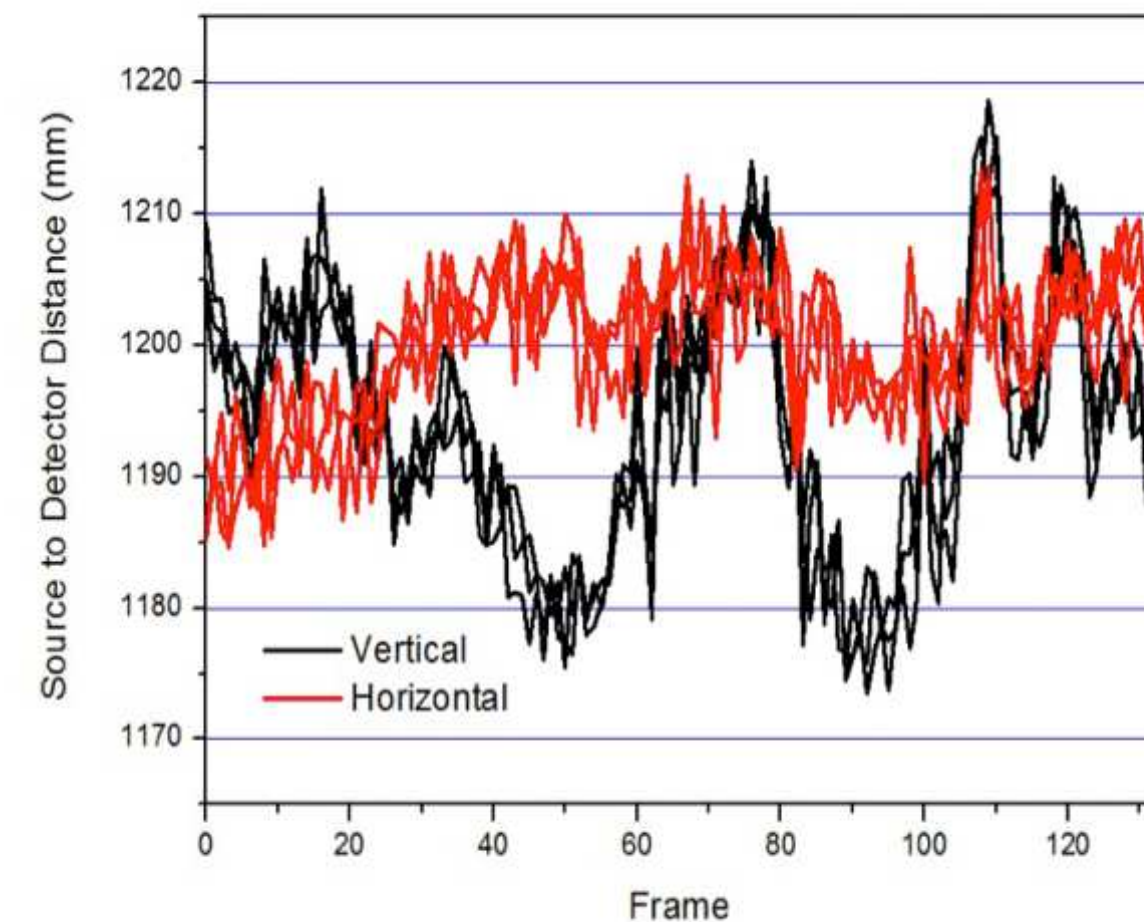
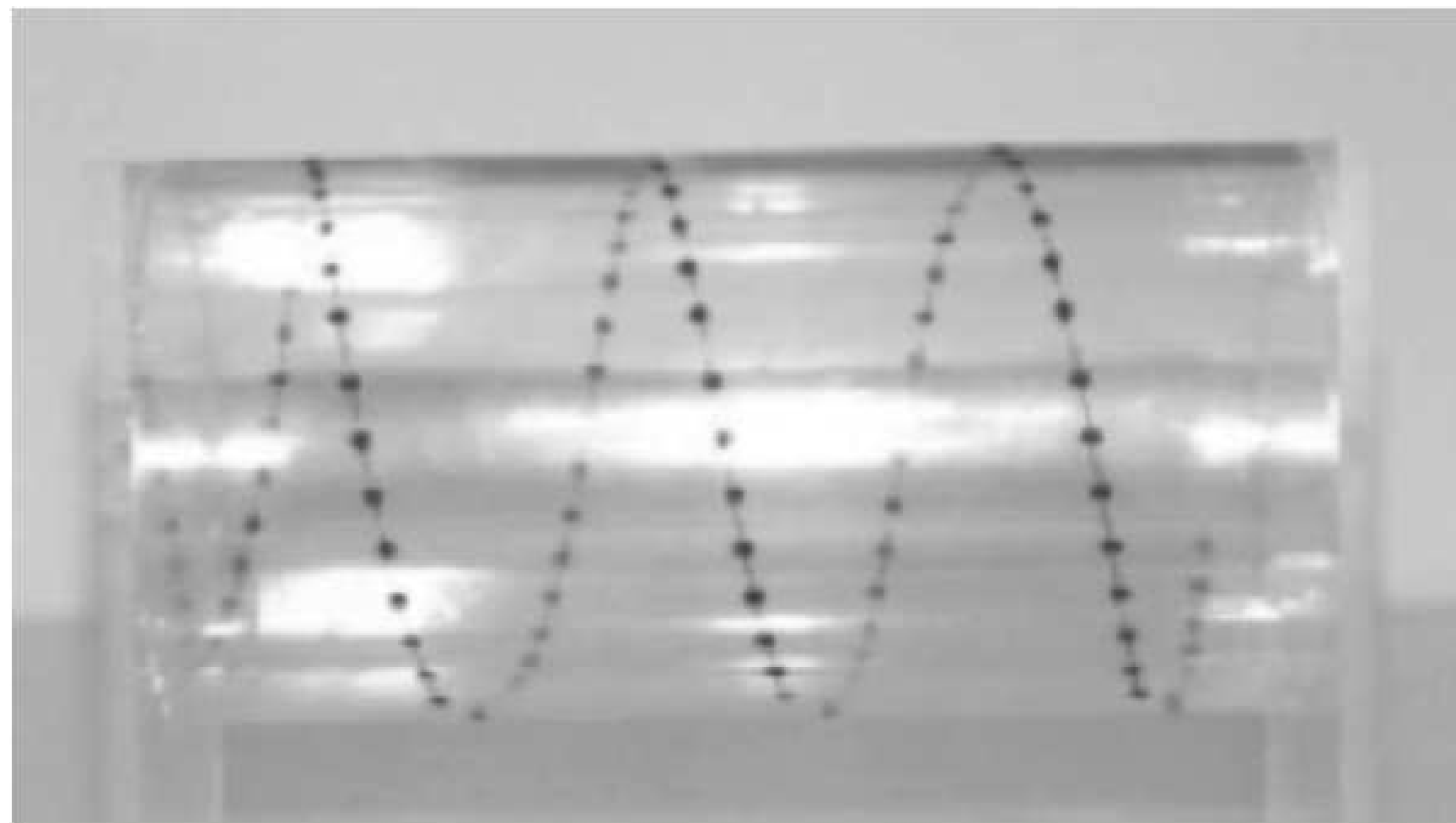


Figure 8: Phantom showing calibration pattern (left) and an example of an evaluation (right)

Topics

Phantoms

Introduction

Numeric Phantoms

Physical Phantoms

Summary

Take Home Messages

Further Readings

Take Home Messages

- Phantoms are one of the fundamental materials used in medical imaging (research).
- Both computational and physical phantoms are developed and used.
- The applications are manifold: algorithm testing, system calibration, dose measurements, image quality assessment, ...

Further Readings

Helpful reads for the current unit:

B. Ohnesorge et al. “Efficient Correction for CT Image Artifacts Caused by Objects Extending Outside the Scan Field of View”. In: *Medical Physics* 27.1 (Oct. 2000), pp. 39–46. DOI: 10.1118/1.598855

L. A. Shepp and Logan B. F. “The Fourier Reconstruction of a Head Section”. In: *IEEE Transactions on Nuclear Science* 21.3 (June 1974), pp. 21–43. DOI: 10.1109/TNS.1974.6499235

W. P. Segars et al. “Realistic CT Simulation Using the 4D XCAT Phantom”. In: *Medical Physics* 35.8 (Aug. 2008), pp. 3800–3808. DOI: 10.1118/1.2955743

A recent book on phantoms in medical imaging:

Larry A. DeWerd and Michael Kissick, eds. *The Phantoms of Medical and Health Physics: Devices for Research and Development*. Biological and Medical Physics, Biomedical Engineering. Springer New York, 2014. DOI: 10.1007/978-1-4614-8304-5