Schulich MEDICINE & DENTISTRY

A Desk-Top Optical Imaging System for Teaching the Principles of Radiography and Computed Tomography

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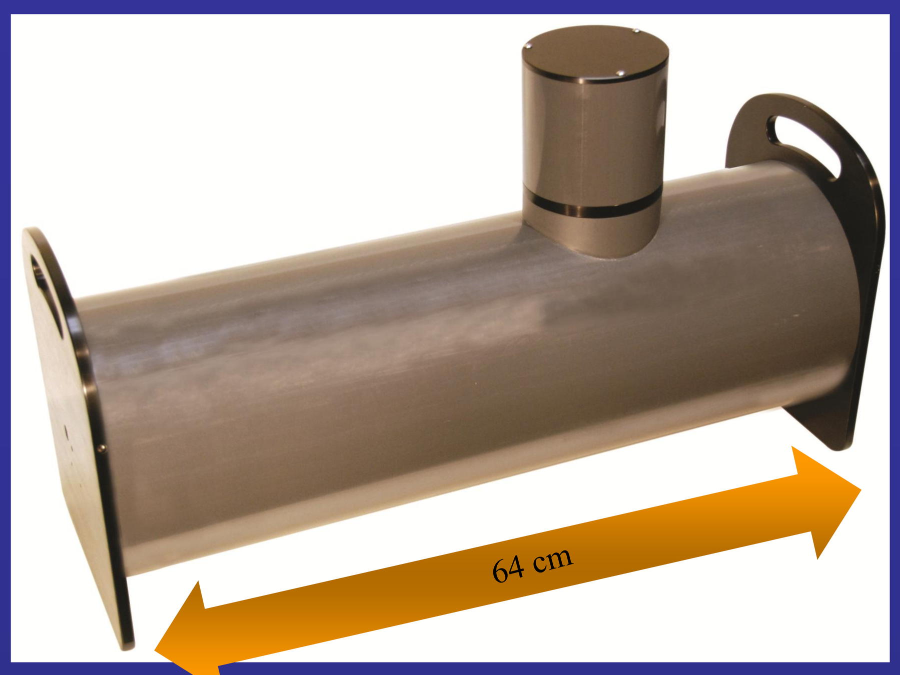
Introduction

- The physical principles of medical imaging are key to understanding clinical imaging procedures
- Basic principles are most often taught through traditional lectures in a classroom setting
- During classroom sessions, access to clinical imaging equipment for demonstration purposes is simply impractical
- The temporal and geographic "gap" between theoretical lectures and practical experimentation can impede the student's learning
- A portable imaging system could be used interactively in the classroom or laboratory to overcome this problem
- We are developing a portable and safe system that can be used to explain and demonstrate the principles of radiography and computed tomography (CT) using light rays instead of x-rays
- A variety of undergraduate students, graduate students, and medical residents can benefit from this development

GOAL

To produce a device and set of lab modules to explain the physical principles of two-dimensional (2D) radiography and three-dimensional (3D) computed tomography (CT) in a classroom or laboratory setting

Method - Optical Imaging System



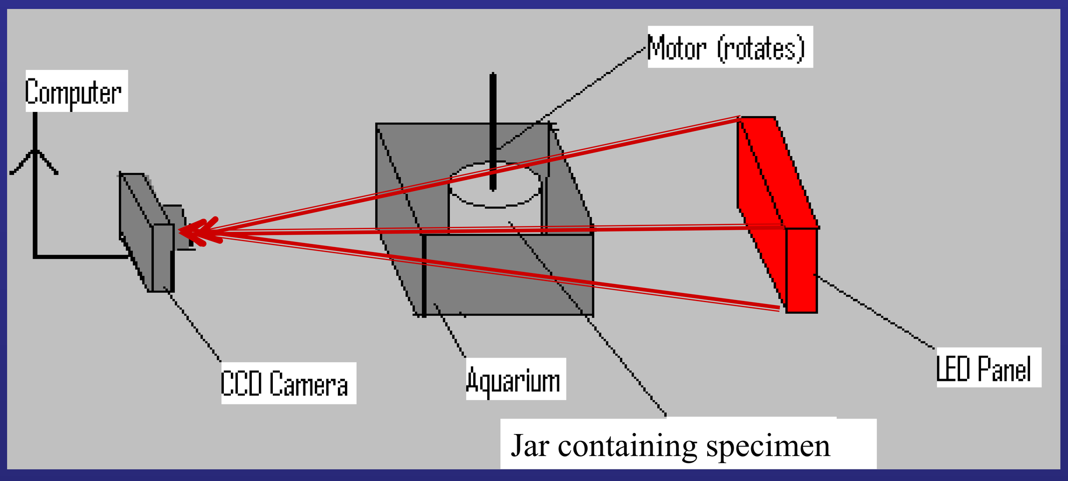


Figure 1 DeskCAT™ optical radiography and CT scanner system (Modus Medical Devices Inc., London, Ontario, Canada)

- The optical imaging system consists of:
  - a lightbox (red) constructed with an array of light-emitting diodes that illuminates the specimen
  - a platform that rotates a cylindrical jar containing the specimen, placed inside the aquarium
  - a CCD camera that records the optical projection images for each projection angle
  - a computer that controls the rotating platform and the camera, and hosts CT image reconstruction and educational display software

- NOTE: This is a cone-beam CT imaging system that is "reciprocal" in geometry compared with a clinical x-ray system. The lightbox is a broad radiation source while the camera is a point detector.

The Problem

- Clinical systems are not readily accessible for medical physics teaching purposes
- Clinical x-ray imaging systems are expensive "black-box" systems in which the components cannot be easily accessed or modified for educational purposes
- Clinical systems use hazardous x-rays and hence the students cannot witness the image data acquisition while the system components are energized or the CT gantry is in motion.

The Solution

- Develop an analogous portable imaging system that uses visible light rays instead of x-rays
- The use of visible light makes the system safe and makes the imaging process observable
- The system is compact, economical, and portable. It can thus be shared across teaching departments with no radiation hazards or interference with clinical operations
- Various demos and laboratory exercises can be tailored for specific groups of students with learning objectives in basic science or medical applications

Method - Specimens

- Translucent specimens that absorb light are used to demonstrate image data acquisition, reconstruction algorithms, 2D/3D display, and quantitative analysis.
- These phantoms are visible and hence their surface and internal content are readily appreciated "by eye" and can be reconstructed mentally "by brain"
- The specimens or phantoms can include internal test objects for determining imaging performance using different imaging parameters
- Optical transmission is measured through the samples using the CCD camera (Figure 1)
- In radiography mode (2D), values at each pixel in the image represent the composite attenuation along each of the rays through the specimen
- In computed tomography mode (3D), the transmission values measured at multiple angles through the specimen are used to reconstruct local attenuation values at each voxel in a reconstructed volume or a slice
- Students quickly appreciate the 2D and 3D aspects of radiography and tomography during interactive data acquisition, and subsequent mage reconstruction and display

Technical Specifications

- Wavelength : 633 nm (red)
- Size of Specimens – Fit cylinder 7.5 cm in diameter
- Radiography Mode: Live images are captured by a CCD camera with acquisition rate:
  - ~10 projections/second
  - Step - and - Shoot Mode
- CT Reconstruction: Feldkamp backprojection

Resolution	3D image Voxel Size (mm)	Approximate Size of Reconstructed Image (MBytes)	Acquisition and Reconstruction Time (minutes)
Low	2	0.25	< 1
Medium	1	2.0	1
High	0.5	16	2
Very High	0.25	128	5

Sample Results

Figure 2 The BillyBee™ honey bear container is filled with blue liquid dye. Radiographic views are shown in grey-tone.

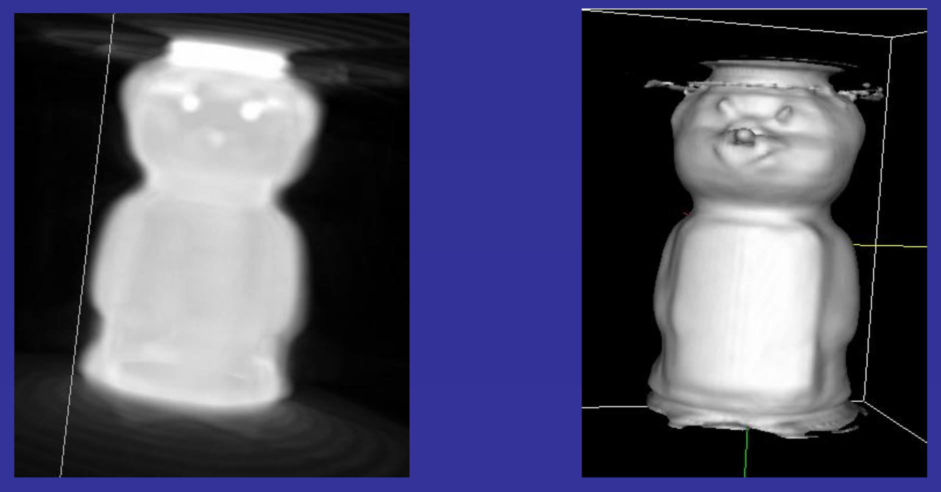


Figure 3 Maximum Intensity Projection (MIP, left) and Surface (right) renderings of the 3D CT data.

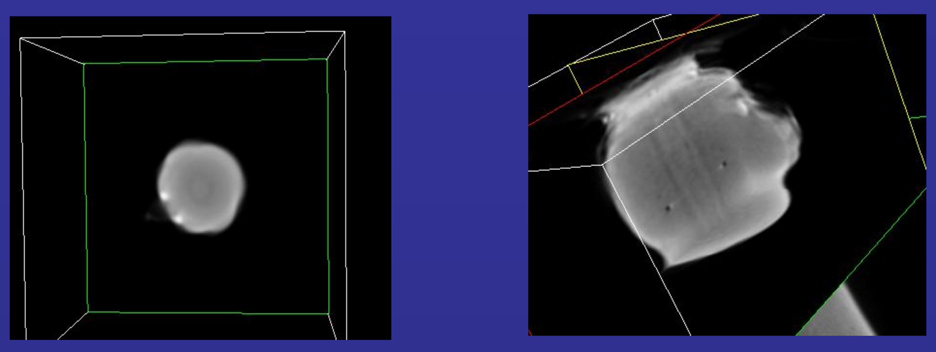


Figure 4 Transverse, and sagittal CT sections of the honey bear. The eyes and small air bubbles are seen.

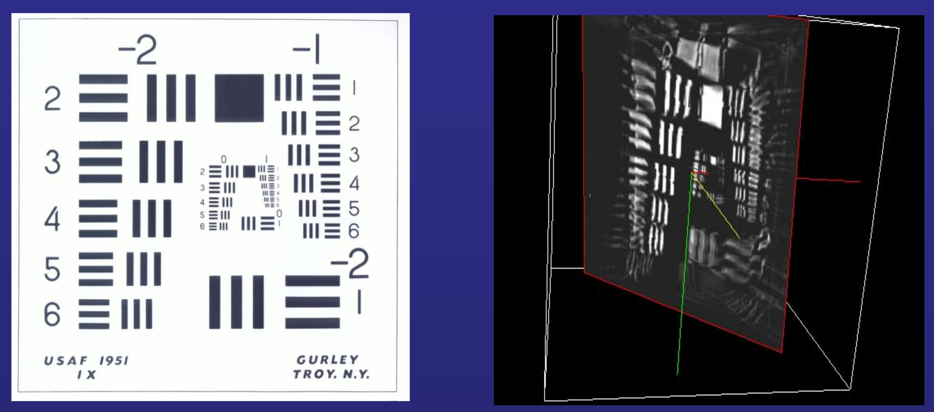


Figure 5 Spatial resolution test film and CT image

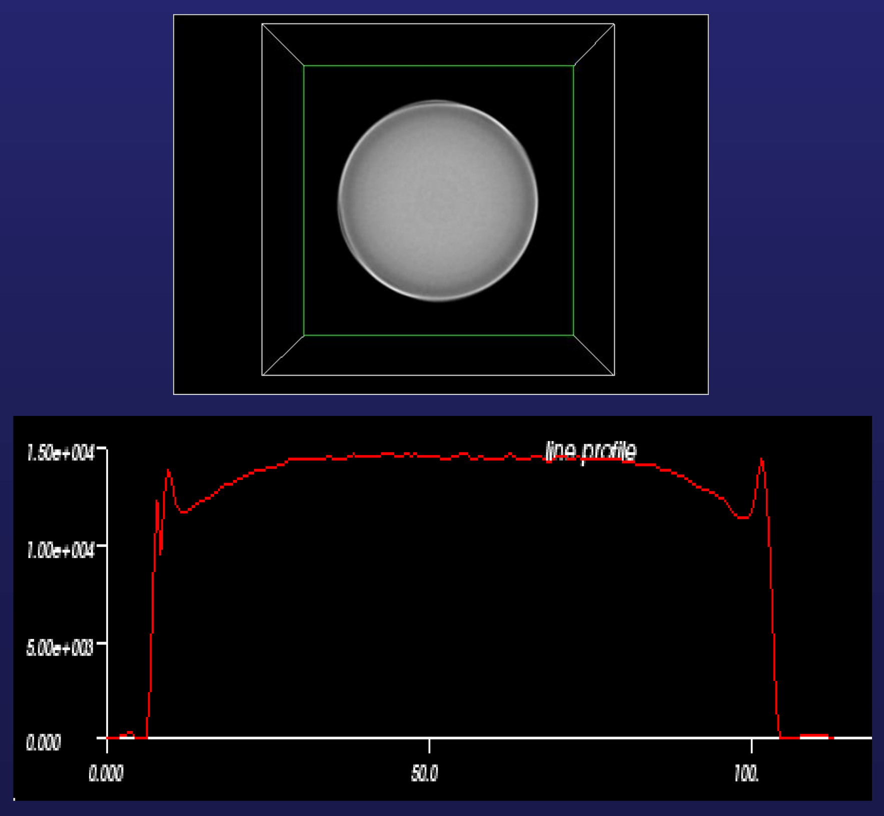


Figure 6 Cross-section of a uniform test cylinder and its corresponding central line profile

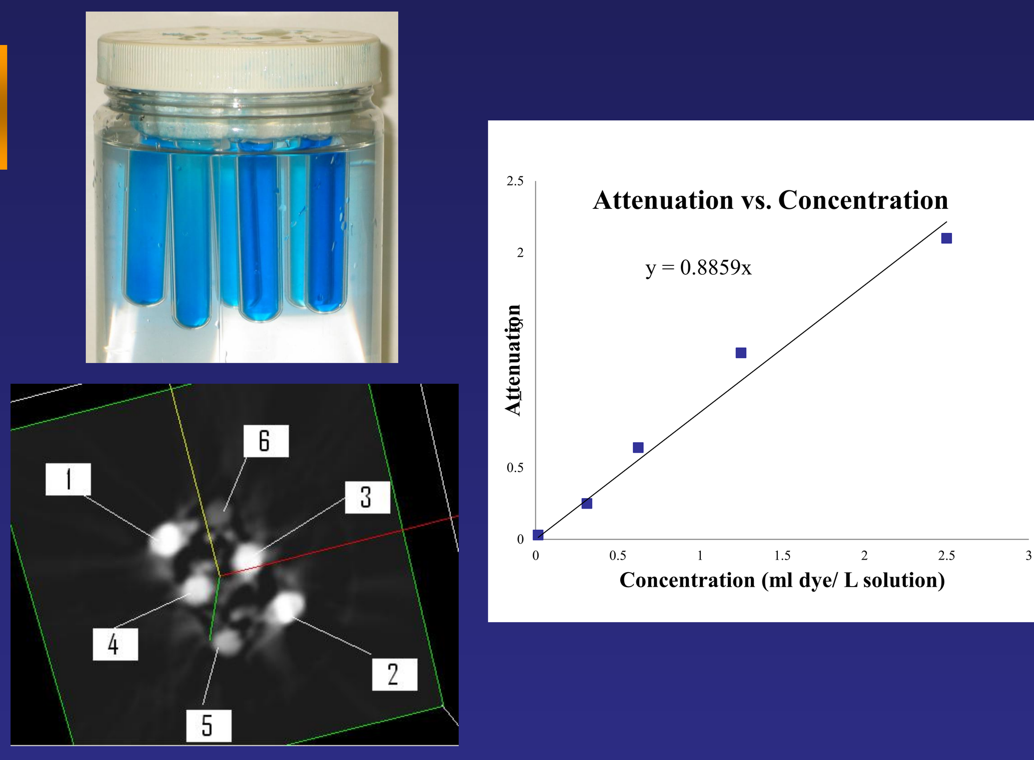


Figure 7 Contrast linearity test using "finger" vials of varying blue dye concentrations (above)

Summary and Discussion

- The principles of radiography and CT are easier to explain and learn using translucent experimental specimens and visible light for image formation
- An optical system and associated laboratory experiments are being developed to introduce these concepts at the senior undergraduate science level, postgraduate MSc/PhD levels, and in medical schools
- Residents in Medical Physics, Diagnostic Imaging, and Radiation Oncology would benefit
- Examples have been presented for diagnostic x-ray techniques used in radiology (radiography and CT)
- Similar experiments could be developed for nuclear medicine imaging (SPECT reconstruction) using light-emitting markers placed in a phantom
- Future options may include multi-wavelength imaging with biomedical applications

Conclusion

- We have presented our progress on the development of an analogous device that uses light rather than x-rays for imaging
- If you are interested in receiving more information, please email the main author at:

j2b@uwo.ca

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