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

J. Battista1,3, R. Taylor3, K. Jordan1,3, J. Miller2, and I. MacDonald3
1 London Regional Cancer Program, 2 Modus Medical Devices Inc., 3 Department of Medical Biophysics, University of Western Ontario, London, Ontario, CANADA

Introduction

The physical principles of medical imaging are key to understanding clinical imaging procedures.
Basic principles are often taught through traditional lecture in a classroom setting.
During classroom sessions, access to clinical imaging equipment for demonstration purposes is impractical.
The temporal and geographic “gap” between theoretical lectures and practical experimentation can hinder student 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

A 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 controlling the 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.

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

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 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 image reconstruction and display.

Sample Results

- Figure 2: The BillyBear™ 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

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:

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References