Digital Radiography

D. J. Hall, Ph.D.

x20893
djhall@ucsd.edu
Background

• **Common Digital Modalities**
  - Digital Chest Radiograph - 4096 x 4096 x 12 bit
  - CT - 512 x 512 x 12 bit
  - SPECT - 128 x 128 x 8 bit
  - MRI - 256 x 256 x 8 bit
  - US - 512 x 512 x 8 or 24 bits

• **Viewing Station**
  - 2k x 2k x 12 bits
Computed Radiography

- **Photostimulable phosphor**
  - Energy trapped on plate
  - Readout at later time
  - BaFBr or BaFI
  - Flexible plate stored in cassette
  - Exposed to x-rays like film
  - Processed in special reader
Computed Radiography

- Photostimulable phosphor - readout

1. The cassette is moved into the reader unit and the imaging plate is mechanically removed from the cassette.
2. The imaging plate is translated across a moving stage and scanned by a laser beam.
3. The laser light stimulates the emission of trapped energy in the imaging plate, and visible light is released from the plate.
4. The light released from the plate is collected by a fiber optic light guide and strikes a photomultiplier tube (PMT), where it produces an electronic signal.
5. The electronic signal is digitized and stored.
6. The plate is then exposed to bright white light to erase any residual trapped energy.
7. The imaging plate is then returned to the cassette and is ready for reuse.
Computed Radiography Reader

- Rotating Mirror
- Light Guide
- Laser
- Imaging Plate
- Translation Rollers
- PMT

Light Emission
**Computed Radiography - emission wavelengths**

![Graph](image)

- **Red** emission peak at around 680 nm
- **Blue-green** emission peak at around 500 nm
- **Stimulation** peak at around 700 nm
Computed Radiography - Dynamic Range

![Dynamic Range Graph]

- CR (Computed Radiography)
- s-f (screen-film)

Optical Density vs. Exposure (mR)

- CR signal
Charge Coupled Devices

- Make images from visible light
- Made of Silicon
- Visible light liberates electrons
  - Electrons accumulate in individual pixel cells
- Accumulated charge readout pixel by pixel
- Requires coupling between light source and CCD
- Used for fluoroscopy and cine-angiography
- Large FOV imaging loses light
  - Proportional to areas of CCD and light source
Charge Coupled Devices - readout

charge packets move in unison

columns

row

readout electronics
Charge Coupled Device - with Image Intensifier
Charge Coupled Device - with fiberoptic coupling
Charge Coupled Device - with lens coupling
Flat Panel Detectors

- Photodetector sensitive to visible light
- Coupled to x-ray intensifying screen
  - $\text{Gd}_2\text{O}_2\text{S}$ or CsI
  - CsI grown in columnar crystals to improve efficiency
- X-rays absorbed in screen give off visible light
- Visible light absorbed in photodetector
  - Fill factor determines efficiency
- Detector size determines best spatial resolution
  - $125 \ \mu\text{m} \rightarrow 4 \ \text{cycles/mm}$
  - $100 \ \mu\text{m} \rightarrow 5 \ \text{cycles/mm}$
Flat Panel Detectors - general configuration
Flat Panel Detectors - fill factor

Fill Factor = \frac{\text{light sensitive area}}{\text{area of detector element}}
Flat Panel Detectors - readout process

Diagram showing the readout process for flat panel detectors, including multiplexer, digitizer, charge amplifier, scan control, and individual detector elements labeled A to I.
Direct detection flat panel systems

- Photoconductor layer on TFT array
  - Direct detection of x-rays - x-ray to electron
  - Not x-ray to light to electron
- Typically Selenium
- Electrons follow E-field lines
  - Relatively thick detectors
Direct detection flat panel systems

- scintillator (CsI)
- TFT detector elements
- glass substrate

x-ray

- electric field
- electrons
- electrode
- selenium layer
- TFT detector elements
- glass substrate
Digital mammography

• Full-field digital mammography
  - Mosaic of CCD detectors
  - TFT flat panel detectors
  - Slot-scan detector
    • 1D detector array
Digital mammography - slot scan detector

- slot beam
- breast
- detector array
- collimator
- detector housing
Digital Mammography - FFDM

Digital Imaging Detector
- Large dynamic range
- Reasonable spatial resolution (300 μm)
- Digital image -> input to CAD system
- Expensive ~ $300k
Digital Mammography - FFDM

Digital Detector

Film-Screen
Digital mammography - slot scan detector readout

slot scan (+V)

breast

charge transfer (-V)

signal train
Patient Dose Considerations - Film vs. Digital

• Need comparable DQE
  - Detected Quantum Efficiency

• CR ~ equivalent to 200 speed film system

• Flat Panel Detectors ~ 2x - 3x faster than CR
Hard Copy vs. Soft Copy

• Resolution varies with modality:
  - SPECT & PET - 128 x 128 pixels
  - MRI - 256 x 256 pixels
  - US - 512 x 512 pixels
  - CT - 512 x 512 pixels
  - Digital angio - 1024 x 1024 pixels
  - Digital chest - 3500 x 4300 pixels
  - Digital mammo - 4000 x 4000 pixels

• Monitor must reproduce data fidelity
Image Processing

- Correct for flaw in image
  - Dead pixels
  - Non-linearities in transfer function
  - "Dark noise"
  - Non-uniformities across field
    - Store "flat-field" image for corrections
Image Processing - correction

raw

corrected
Image Processing - global adjustment

- wide
- narrow
- inverted
Image Processing - convolution

- Mathematical process
  \[ g(x) = \int_{x'=-\infty}^{+\infty} I(x') h(x-x') dx' \]

- Permits image enhancement
  - Computationally efficient
  - Various operations (kernels):
    - Soft tissue - smoothing
    - Bone - edge enhancement
Image Processing - convolution
Image Processing - convolution

- Original
- 11x11 smooth
- Edge enhance
- Edge - smooth
Image Processing - histogram equalization
Contrast versus Spatial Resolution

- SF Mammography
- TFT Digital
- CR
- SF

MTF (%) vs. Spatial Frequency (cycles/mm)
Geometric Tomography

tomographic angle

focal plane

cassette
Geometric Tomography

- focal plane
- cassette
- position of shadows (B)
- position of shadows (A)
Geometric Tomography - slice sensitivity profile

- 30° tomographic angle
- 10° tomographic angle

Relative Contrast (%)

Distance below focal plane
Distance above focal plane

focal plane
Digital Tomosynthesis
Temporal Subtraction

Mask Image

Mask with Dye

Subtraction Image

Stenosis = 1 - \frac{B}{A}
Radiology Physics Lectures: Digital Radiography

Dual Energy Subtraction

One-pulse sandwiched detector  Two-pulse single detector
Dual Energy Subtraction

Low

High

Bone

Soft tissue
7. Digital subtraction angiography (DSA) typically produces the subtracted images using which arithmetic on the mask and iodinated images?

A. Simple linear subtraction.
B. Logarithmic subtraction.
C. Exponential subtraction.
D. Addition with scaling.
E. Fourier-based reconstruction.
7. Digital subtraction angiography (DSA) typically produces the subtracted images using which arithmetic on the mask and iodinated images?

A. Simple linear subtraction.
B. Logarithmic subtraction.
C. Exponential subtraction.
D. Addition with scaling.
E. Fourier-based reconstruction.

7. Logarithmic amplification is used in order to linearize the exponential attenuation of the iodinated contrast so that the difference is a linear function of the contrast concentration and thickness.
Which of the following is true in regards to geometrical tomography?

A. Geometrical tomography is one of the lowest dose procedures performed in radiology.
B. Geometrical tomography has better contrast resolution than computed tomography.
C. Geometrical tomography can be performed using a computed radiography (CR) cassette.
D. The scattered radiation in geometrical tomography is far less than that of projection radiography.
E. Scan angles greater than 90° are required.
Review Question

10. Which of the following is true in regards to geometrical tomography?

A. Geometrical tomography is one of the lowest dose procedures performed in radiology.
B. Geometrical tomography has better contrast resolution than computed tomography.
C. Geometrical tomography can be performed using a computed radiography (CR) cassette.
D. The scattered radiation in geometrical tomography is far less than that of projection radiography.
E. Scan angles greater than 90° are required.

10. C. Geometrical tomography can be performed with any planar x-ray detector that has an integrate mode.
12. Dual energy subtraction imaging requires the following:

A. Temporal differences between two images must exist.
B. The effective energies of the two separate acquisitions must be identical to maintain subtraction image quality.
C. The x-ray energies used to acquire two images must be substantially different.
D. The amount of laser energy used for CR plate readout must be different.
E. Energy sensitive, photon-counting detector systems are needed.
Review Question

12. Dual energy subtraction imaging requires the following:

A. Temporal differences between two images must exist.
B. The effective energies of the two separate acquisitions must be identical to maintain subtraction image quality.
C. The x-ray energies used to acquire two images must be substantially different.
D. The amount of laser energy used for CR plate readout must be different.
E. Energy sensitive, photon-counting detector systems are needed.

12. C. Dual energy radiography relies on the differential attenuation of one material that has strong energy dependence (e.g., bone) and one material that has less energy dependence (e.g., soft tissue). By weighting the high and the low energy images with an appropriate constant allows the elimination of one tissue (e.g., bone for a soft-tissue image) when the images are subtracted. This requires images that are acquired at substantially different x-ray energies.