Dual Energy Imaging with Dual Source CT Systems

Rainer Raupach, PhD
Siemens Healthcare
rainer.raupach@siemens.com

Dual Energy Radiography

Radiograph  Bone image  Tissue image

2 energies \rightarrow 2 materials


kV Switching with SOMATOM DRH – in the 80s

- Calculation of material selective images:
  - Calcium and soft tissue

\[ \text{Mean Energy} \]

\[
\begin{align*}
\text{Tube 1} & : 56 \text{ kV} \\
\text{Tube 2} & : 76 \text{ kV}
\end{align*}
\]

Data acquisition with different X-ray spectra: 80 kV / 140 kV

Principle of Dual Energy CT

- Different mean energies of the X-ray quanta
**Principle of Dual Energy CT**

- Many materials show different attenuation at different mean energies

![Graph showing attenuation at different mean energies](image)

- Reason: different attenuation mechanisms (Compton vs photo effect)

**SOMATOM Definition**

The World’s First Dual Source CT

- Faster than Every Beating Heart
  - gated mode / same kV
  - high temporal resolution (80ms)
  - Cardiac imaging

- One-Stop Diagnosis in Acute Care
  - non-gated mode / same kV
  - low temporal resolution
  - Obese patients, low kV scanning

- Beyond Visualization with Dual Energy
  - different kV (gated and non-gated)

**Spectra of Dual Energy Applications**

- Basic application: Enhanced viewing, contrast optimization
- Contrast enhanced studies: Iodine has much higher contrast at 80 kV
- Non-linear, attenuation-dependent blending of the images combines benefits of 80 kV (high contrast) and mixed data (low noise)

“Contrast Enhanced Viewing” using Dual Energy

Information in Addition to Simple Image Mixing
**syngo Dual Energy**

**Direct subtraction of bone**

- Modified 2-material decomposition: Separation of two materials
  - Assume mixture of blood + iodine (unknown density)
  - and bone marrow + bone (unknown density)

**syngo Dual Energy**

**Direct subtraction of bone**

- Modified 2-material decomposition: Separation of bone and iodine
- Automatic bone removal without user interaction
  - Clinical benefits in complicated anatomical situations:
    - Base of the skull
    - Carotid arteries
    - Vertebral arteries
    - Peripheral runoffs

**Image Based Methods**

- Modified 2-material decomposition: Characterization of kidney stones
  - Urine + calcified stones / uric acid stones
**SOMATOM Definition**
- World’s first DSCT
- Spatial Res: 0.33 mm
- Rotation: 0.5 sec
- Scan time: 4 s
- Scan length: 133 mm
- $140/80$ kV
- $E_{eff} 80/150$
- Spiral Dual Energy

**Applications of Dual Energy CT**
- Three material decomposition: quantification of iodine – iodine image
- Removal of iodine from the image: virtual non-contrast image
Image Based Methods

- Most promising application: 3-material decomposition
  - Calculation of a virtual non-contrast image, iodine quantification

Applications of Dual Energy CT

- Virtual non-contrast image and iodine image:
  - Characterization of liver / kidney / lung tumors
  - Solve ambiguity: low fat content or iodine-uptake
  - Quantify iodine-uptake in the tumor and at the tumor surface
  - Differentiation benign - malignant
  - Monitoring of therapy response

Applications of Dual Energy CT

- Quantification of iodine to visualize perfusion defects in the lung
  - Avoids registration problems of non-dual energy subtraction methods

SOMATOM Definition Flash
Latest Generation of Dual Energy CT

System Design

- Two X-ray tubes at 95°, each with 100 kW
- Two 128-slice detectors, each with 64x0.6mm collimation and z-flying focal spot
- SFOV A/B-detector: 50/33 cm
- 0.28 s gantry rotation time
  75 ms temporal resolution
SOMATOM Definition Flash
Single dose Dual Energy

D OSE - neutral DE: comparison of 120 kV and 100 kV/140 kV+0.4 mm Sn

Images acquired and processed in collaboration with CIC Mayo Clinic Rochester, USA
New Application Classes

- Measurement of Lung Nodule enhancement
- Measurement of Xenon Concentration
- Mono-energetic imaging

Dual Energy CT

- Are there alternative approaches?
  - Sequential acquisition at 80 kV and 140 kV with single source CT
  - Registration problems (heart/lung motion, varying contrast density)
  - Fast kVp-switching during the scan with single source CT
  - Inadequate power at low kV
  - Unequal noise for low and high kV data
  - Spectral sensitive „sandwich“ detectors
  - Inferior spectral separation
  - Quantum counting
  - Paralysis at high flux rate
  - Spectral overlap by fluorescence and pile-up

Dual Energy CT Performance

- Dose
- Phantom diameter [cm]
- Relative DE MC²

Thank you!