Spektr: A computational tool for x-ray spectral analysis and imaging system optimization

Siewerdsen, J. H., et al. "Spektr: A computational tool for x-ray spectral analysis and imaging system optimization." *Medical physics* 31.11 (2004): 3057-3067.

Presented by Michael Mudgett

Project Recap

- "Low Dose Fluoroscopy for Orthopedic Surgery"
  - Pelvic Fracture
- Goals:
  - Reduce amount of radiation received by patient
  - Speed up surgical procedure
- Generate x-ray images and train a neural network to improve low dose image quality, negating need for many high dose digital radiographs

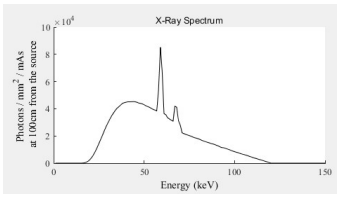
My Task: Image/Dose Simulation

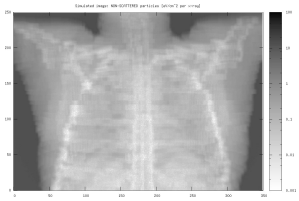
CT Volume

Parameters

- # Photons
- CT Location
- Emitter Location
- Detector Location
- Material info

X-Ray Spectrum



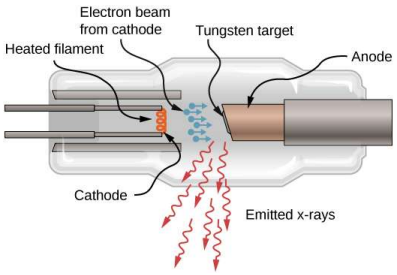


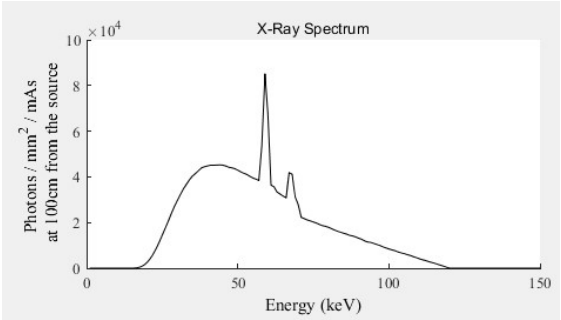
Paper Selection

- Needed a program to effectively generate x-ray spectra
  - Experiment with different dose parameters
- Many factors govern the shape of a spectrum
- Hard to find data/way to generate spectra

Background

- X-rays produced when electrons collide with anode
- Photons of varying energies are emitted
- Spectrum illustrates proportion of photon energies





Key Result

- Developed a model to generate x-ray spectra
  - Histogram of photon density vs photon energy (keV)
- Added flexibility to allow for a wide range of kVp, added filtration, etc.
- Written in MATLAB, implemented a GUI

Methods

- Tungsten Anode Spectral Model using Interpolated Polynomials "TASMIP" (Boone & Seibert) for Energy function
  - Switched to TASMICS (cubic splines) for Spektr 3.0
- Beer's law of exponential attenuation for filtration effects

$$\text{if } E \leqslant \text{kV}, \Phi[E] = a_0[E] + a_1[E]\text{kV} + a_2[E]\text{kV}^2 + a_3[E]\text{kV}^3 + \cdots + a_n[E]\text{kV}^n,$$

$$\text{else } \Phi(E) = 0.$$

$$T = e^{-\mu \ell}$$

Validation

- Program calculations agree with experimental measurements

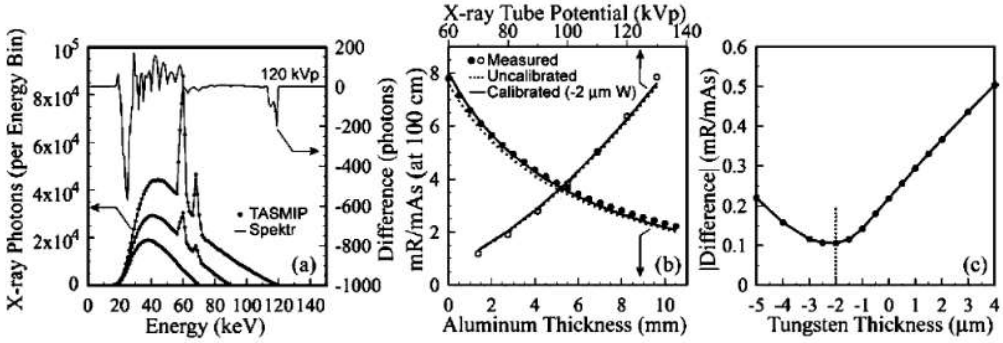


FIG. 1. Validation of Spektr calculations. (a) Comparison of TASMIP and Spektr calculations at 70, 90, and 120 kVp (left axis). Each case assumed 2.5 mm Al filtration and 5% kV ripple. The absolute difference between the spectra at 120 kVp is plotted on the right axis. (b) Tube output (mR/mAs) at 100 cm from the source as a function of added Al filtration (lower axis) and kVp (top axis). Measured values are plotted as solid and open circles, and Spektr calculations are shown as dashed and solid lines. (c) Difference between measured and calculated mR/mAs as a function of tungsten thickness. Calibration by -2 μm W filtration in Spektr calculations was found to minimize the discrepancy between measured and calculated values, improving agreement as shown in (b) for the solid ("calibrated") curve.

Discussion

- Program lacks features which would make it more realistic
  - Assumes x-ray tube can tolerate any heat load
- Did not thoroughly test performance with multiple filtration layers
- Many possible features that could be implemented in future
- Can be used to determine optimal physical configurations

Evaluation

Pros	Cons
Easy to use, accessible model	Little validation with real measurements, large analysis of theoretical results
Thorough explanation of calculations	No comparison to other models
Suggests features for future iterations and specific applications	Potential deviations from a “true” system (unavoidable)

Relevance/Conclusions

- Allows me to quickly and accurately generate x-ray spectra for image and dose simulation
- Easy to use
- Flexibility to vary parameters
- Outputs spectrum data into format which the simulating software can interpret

Thank you!

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- Mentors: Mathias Unberath, PhD, Nico Zaech, Bastian Bier
- Faculty: Nassir Navab, PhD, Greg Osgood, MD