Dual Energy CBCT
Current progress and potential applications

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Disclosures

• I am employed by ELEKTA
• I receive royalties through WARF for tomotherapy patents
• Collaboration researchers have received funding from ELEKTA

• MSE = VARIANCE + BIAS
• I’ll do my best to acknowledge the latter and minimize the former

Back in the day...
When Dual Energy required liquid nitrogen and wire-wrapped circuit boards

• “A prototype high-purity germanium detector system with fast photon-counting circuitry for medical imaging”
  - First published: September 1991
  - Hasegawa, et. al.
  - https://doi.org/10.1118/1.596606

Between 1986-1988, I participated in some of the work that the above publication utilized.
A quick tour of the tech
Different ways of acquiring Dual Energy CT

- Photon Counting
- Layered detectors
- High Speed Switching kVp
- Dual pass/Sequential acquisition
- Split detectors
- Dual source (and separate detectors)

Potential applications for DE CBCT (Goals)
Not necessarily the same as for DE CT

- Improved soft tissue contrast
- Reduction of high-Z artefact (e.g., Titanium implants)
  - Improve patient positioning based on soft tissue information rather than bone.
  - Improve patient positioning based on bone when there are implants
  - Improve Deformable Registration (due to improved soft tissue contrast)
- Distinct from material composition/Stopping power desired for PT
  - Which is also desirable if the CBCT is for PT...

Contrast (to Noise) is King
But (CNR / Dose) as a metric and a goal is quite important

- Reference CT
- CBCT
- Reference MR
Modern data, not matching but indicative of current quality

Previous slide had matching data, but very old

- CT
- CBCT
- MR

Dual Energy CBCT difference from Dual Energy CT

different modes of acquisition, different issues, and different goals

- DE CBCT shares the classic CBCT issues re: scattering and volumetric FOV
  - But one can exploit the advantage of a slower rotation/acquisition
  - Trigger the x-ray source to emit x-radiation at a second x-ray energy differing from the first x-ray energy when the angular encoder reports that the gantry is at each of the same predetermined angular locations.
  - i.e. dual scan, but accurate registration of the projection images

Previous literature on DE CBCT

- Dual-energy cone-beam CT with a flat-panel detector: effect of reconstruction algorithm on material classification.
  - Zbijewski W, et. al.
- Dual Energy Cone Beam Computed Tomography for Image Guided Radiation Therapy
  - D.G. Kovacs, et. al.
  - DOI: https://doi.org/10.1016/j.ijrobp.2016.06.2352
Current research

- Sunnybrook
  - Iterative reconstruction
    - Dual Energy imaging involves subtraction of signal (but addition of noise)
  - Artifact reduction
    - Low Frequency Artifact Correction (scatter)
    - Beam Hardening Correction
    - Metal Artifact Correction
  - However, current mode of acquisition is not based on the dual scan/angular encoder method

Possible future areas for research

- Multi-layer Spectral detectors (back to the future!)
- Operate in projection space with priors (scatter reduction)
- Dual Priors (for DE CBCT) based on DE CT (dual datasets)
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Thank you
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