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/10.1118/1.596606I**

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)

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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…

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Contrast (to Noise) is King

But (CNR / Dose) as a metric and a goal is quite important

- Reference CT
- CBCT
- Reference MR

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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
  - US 9,414,790 B2/Aug.16, 2016

  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.
  - Med Phys. 2014 Feb;41(2):021908. doi: 10.1118/1.4863598.
  - 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

- Review of DECT: **Dual-Energy CT: General Principles,** AJR:199, November 2012, T. R. C. Johnson, DOI:10.2214/AJR.12.9116

Current research

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

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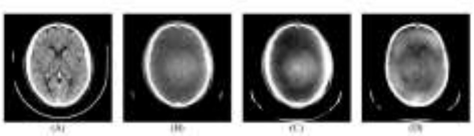
Simulation Results

Courtesy of Masoud Hashemi, Sunnybrook, exclusive of DE decomposition



Comparing the visibility of ventricles and homogeneity improvement. (A) CT image chosen as the ground truth for corrected CBCT images, (B) clinical CBCT image, (C) image reconstructed with SDIR, and (D) image reconstructed with the proposed framework. The quality of the image reconstructed with CALI (D) is comparable with the CT image (A).

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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Sunnybrook

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Elekta collaborators

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Thank you

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