

A convolutional neural network approach with dual-energy computed tomography for proton stopping-power-ratio estimation

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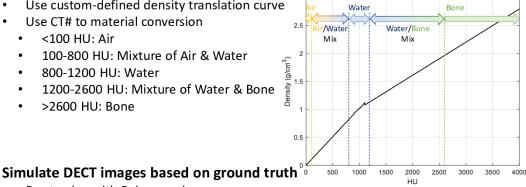
INTRODUCTION

Analytical stopping-power-ratio (SPR) estimation methods using dualenergy CT (DECT) have limitations in resolving the influence from the beam-hardening artifact, i.e., CT number variation of the same object scanned under different imaging conditions, such as different patient size and location in the field-of-view (FOV). We present a convolutional neural network (CNN)-based framework to estimate proton SPR that accounts for patient geometry variation and addresses CT number variation. The proposed framework was tested on prostate and headand-neck (HN) patient datasets with two training scenarios: training with patient CT images (ideal scenario) and training with computational phantoms (realistic scenario).

METHODS

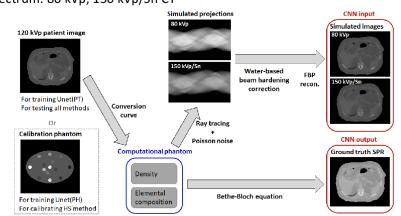
Calculate ground truth of patient CT images and computational phantoms

- Use custom-defined density translation curve
- Use CT# to material conversion
- <100 HU: Air
- 100-800 HU: Mixture of Air & Water
- 800-1200 HU: Water
- 1200-2600 HU: Mixture of Water & Bone
- >2600 HU: Bone



Ray tracing with Poisson noise

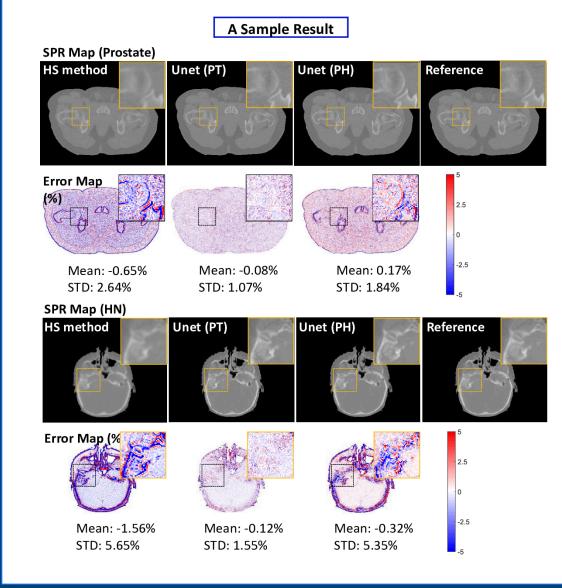
Spectrum: 80 kVp, 150 kVp/Sn CT

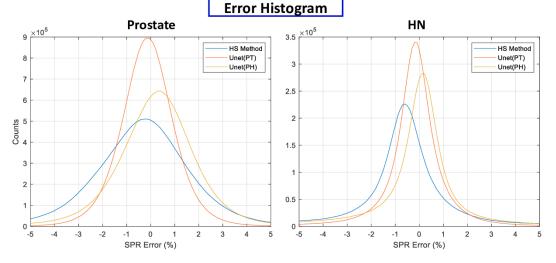


Use CNN to estimate SPR from simulated DECT images

- Ideal scenario (Unet(PT)): train with patient images
- Realistic scenario (Unet(PH)): train with computational phantoms of 5 different size
- Compare with a conventional DECT method (HS method) from Li et al., 2017 PMB
- Test on a reserved set of patient images not used in the ideal scenario

RESULTS





	Prostate			HN		
	ME	STD	Uncertainty	ME	STD	Uncertainty
HS method	-0.52	2.92	1.10	-1.16	4.77	2.11
Unet (Patient)	-0.08	1.21	0.32	-0.13	1.45	0.42
Unet (Phantom)	0.28	2.16	0.71	-0.31	4.44	1.20

Quantitative Results

Uncertainty = abs(ME) +
$$\frac{2}{\sqrt{}}$$

Quantitative results on 40 patients (800 images, ~30M pixels) suggest that:

- HS method performed decently (~1% uncertainty) on prostate data, but not on HN data
- Unet(PT) yielded close to zero uncertainty
- Unet(PH) performed significantly better than HS method, presumably reducing the impact from CT number variation

CONCLUSIONS

Results from the U-net model trained with phantom data (Unet(PH)) shows the feasibility of using CNN in a realistic condition for accurate SPR estimation by incorporating geometric variations into the training. Unet trained with patient data (Unet(PT)) further shows the potential of CNN that the model is capable of reducing the error close to zero. We look forward to improving the Unet(PH) model with more efficient training data and/or architecture.

REFERENCES

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