Development of Multiple X-ray Source Cone-Beam Computed Tomography

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Motivation

- Radiation therapy (RT) is one of the most effective modalities for cancer treatment [1]
- Image-guided radiation therapy (IGRT) uses "real time" imaging technologies to eradicate tumors without damaging normal tissue [2]
- Cone-beam computed tomography (CBCT) is commonly used for IGRT

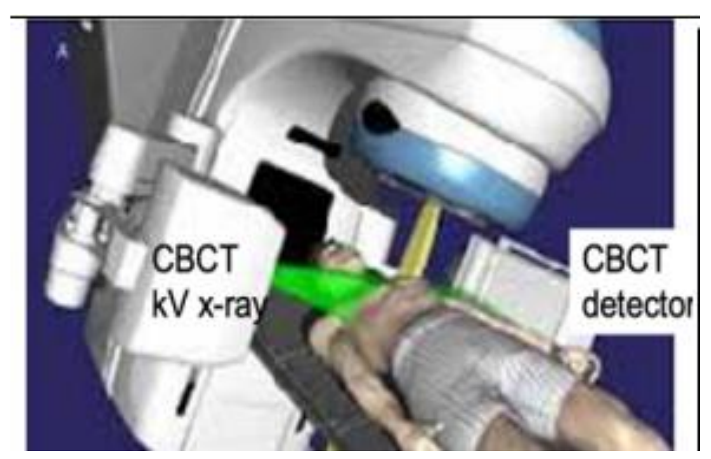


FIG 1. An illustration of an IGRT system

- However, CBCT has some intrinsic limitations, such as poor contrast, unwanted image artifacts, and inaccurate numerical values [3]

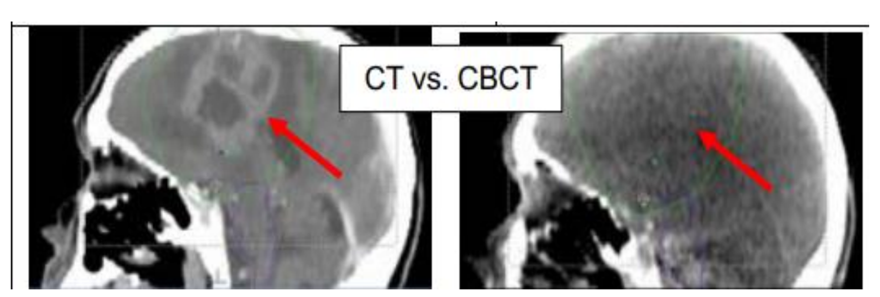
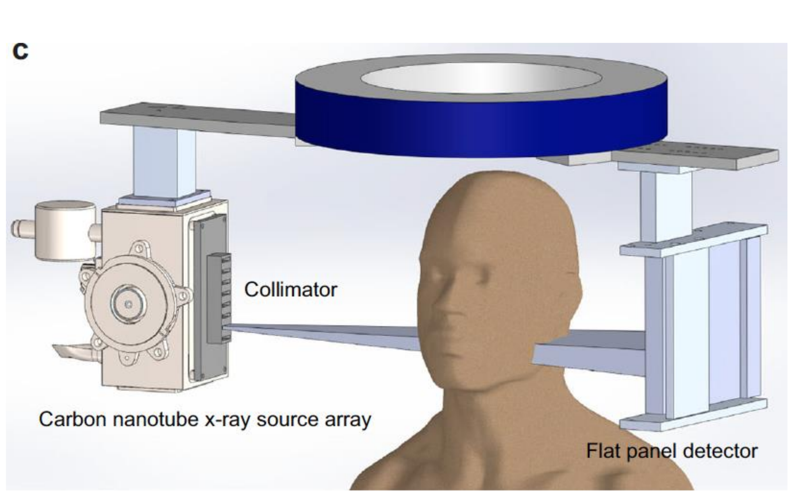


FIG 2. CT (left) and CBCT (right) images of a brain tumor, which is clearly visualized in CT but hardly seen in CBCT (UNC data).

FIG 3. An illustration of the dental ms-CBCT system [4]



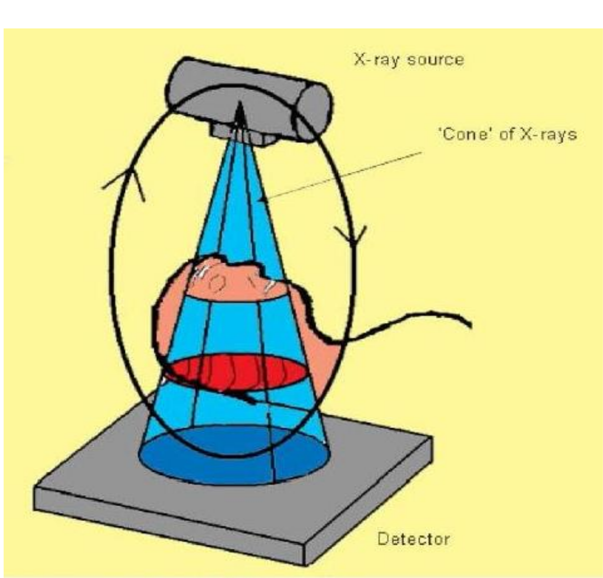


FIG 4. An illustration of how a CBCT device works.

- A multiple x-ray source CBCT (ms-CBCT) has been shown on dental and head scans to overcome these limitations
- To further study this, we aim to test ms-CBCT on a larger system, to explore it's benefits for IGRT applications

Methods

- The project designed a benchtop X-ray imaging system
  - ➢ carbon nanotube X-ray source
  - ➢ 30x30cm flat panel detector
  - ➢ Kyoto LUNGMAN chest phantom used for imaging
  - ➢ Collimation of X-ray beam allows for manual changes to investigate the effects of the cone angle

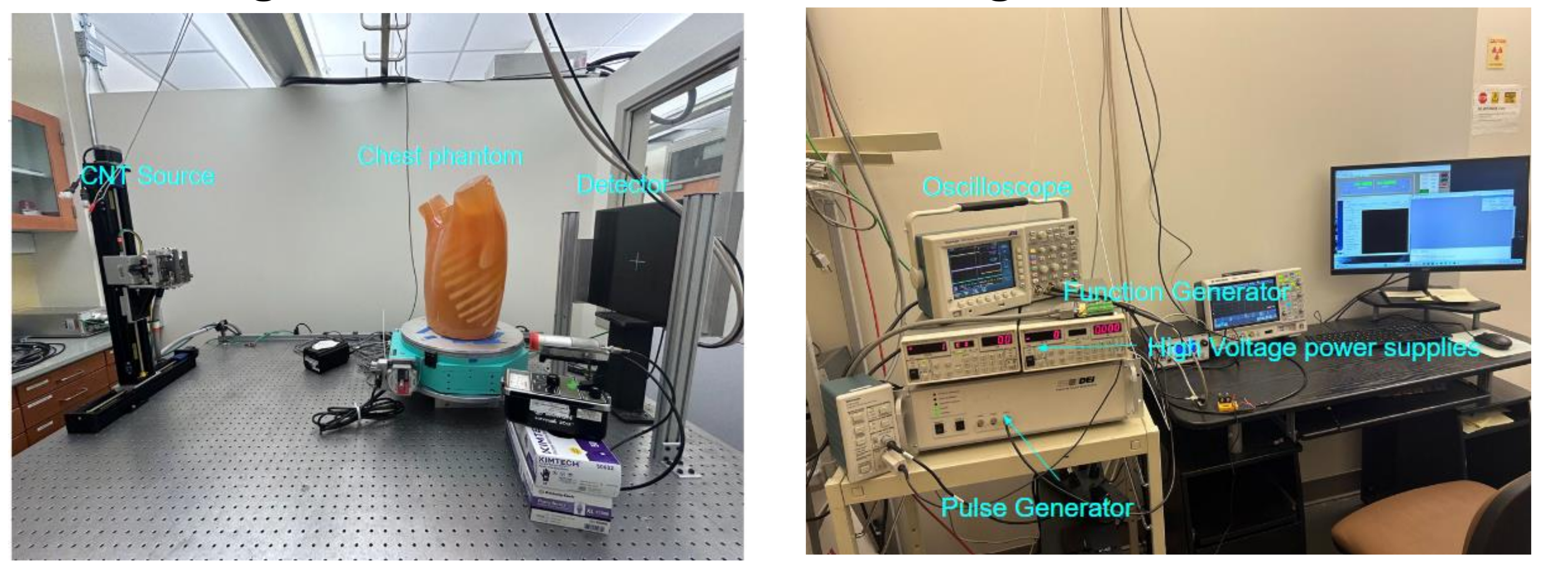
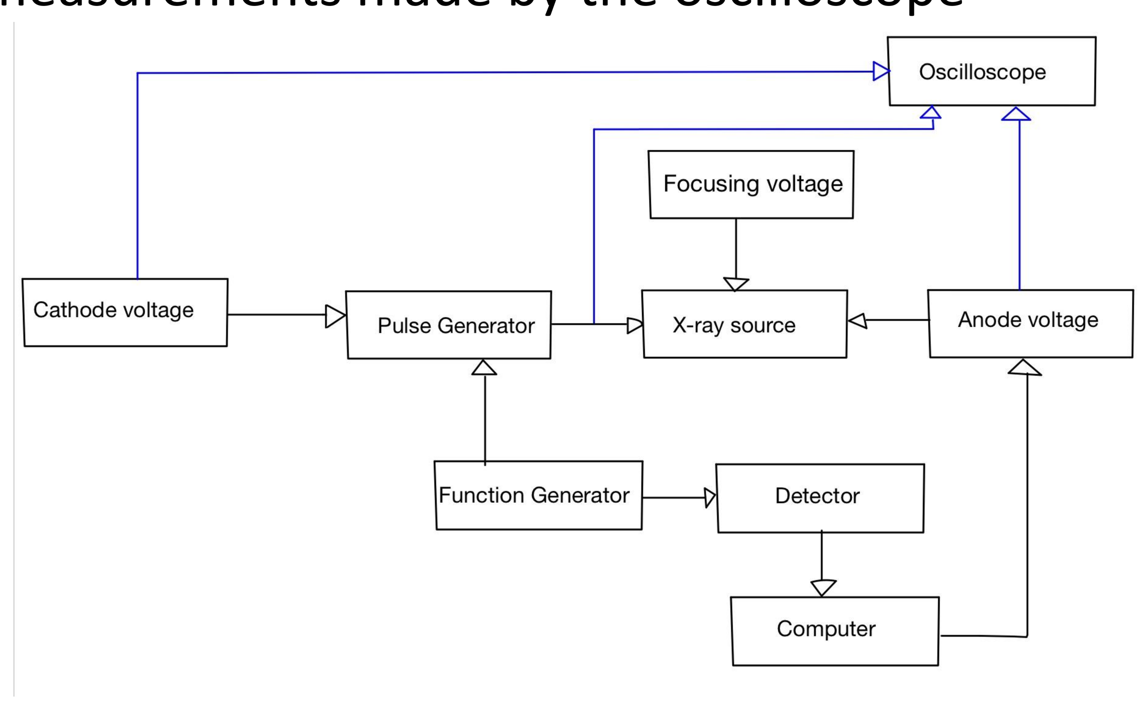


FIG 4. System Setup

- Parameters used for this system

- Source-to-Object (SOD) distance : 100cm
- Object-to-Detector (OOD) distance: 50cm
- Source-to-Detector (SID) distance: 150cm
- Fan Angle: 8.531 degrees
- Cone Angle: 1.618 degrees

FIG 5. Schematic of devices used. Blue lines represent measurements made by the oscilloscope



- Experiment conducted to investigate how scatter is affected by decreasing the cone angle, narrowing the beam
- Experiment conducted to investigate how numerical values and image quality are improved by decreasing the cone angle, narrowing the beam

Results and Next Steps

- Results confirm expected improvement in image quality, decreased scatter, and numerical values for small angle reconstructed images compared to large angle reconstructed images

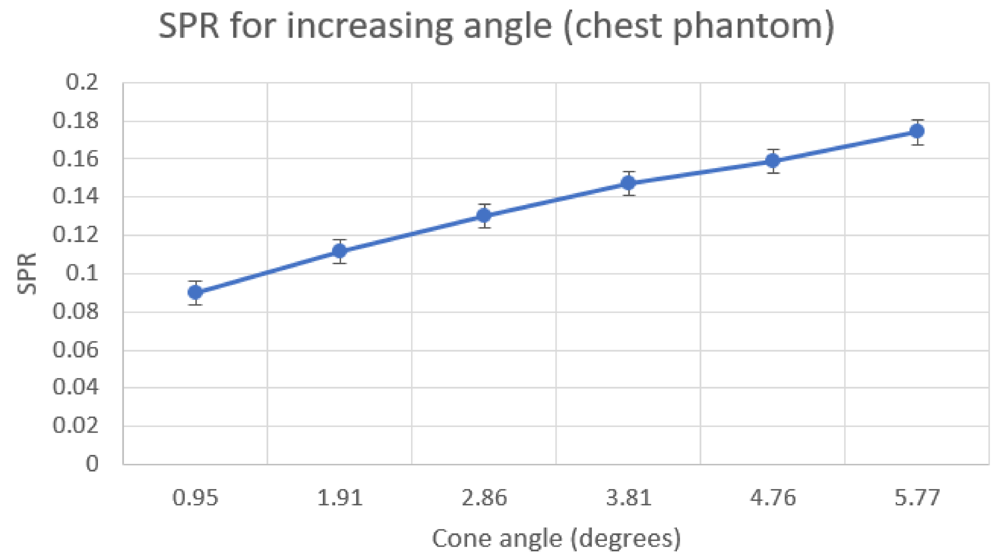


FIG 6. SPR as a function of cone angle
Error bars calculated using standard error

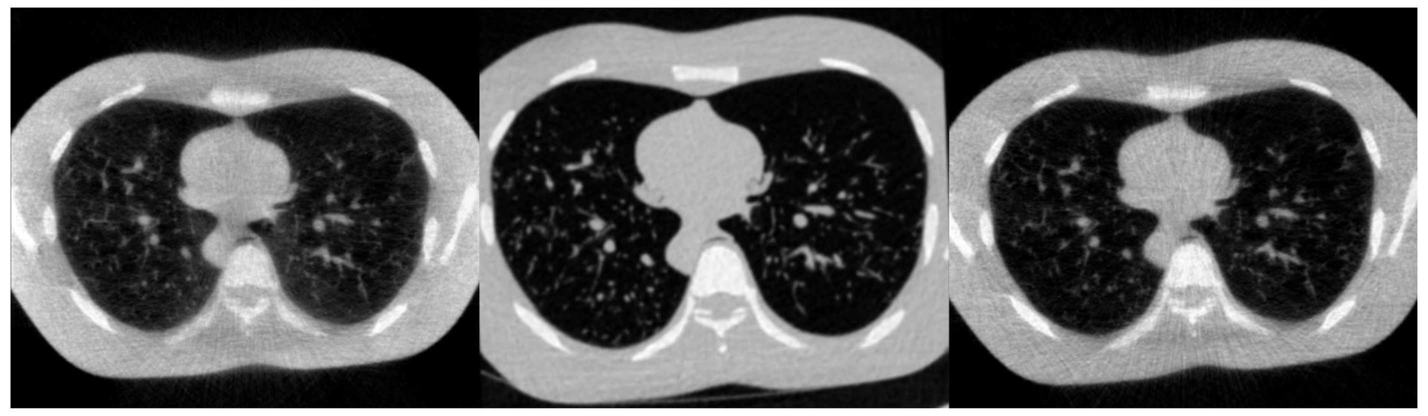


FIG 7. Left: Large angle reconstructed image. Center: clinical CT of same chest phantom for comparison. Right: Small angle reconstructed image

Type of material	Clinical CT	Large Angle	Small Angle
Air	HU -1000.514 SD:16.290	HU: -999.407 SD:7.820	HU: -996.672 SD: 15.743
Bone	HU: 368.082 SD:41.974	HU: 8.347 SD: 71.901	HU: 326.615 SD:108.337
Heart	HU: 42.790 SD:32.747	HU: -223.508 SD:61.632	HU: -39.404 SD: 91.476
Lung	H: -914.906 SD:158.541	HU: -889.168 SD:98.916	HU: -900.758 SD:124.781
RMSE	Reference	224.158	46.611

FIG 8. Numerical values for clinical CT, large angle, and small angle images

- Future steps: generate a full ms-CBCT reconstructed image for comparison with a single-source CBCT image, highlighting the advantages of ms-CBCT in conjunction with IGRT

Acknowledgements

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References:

[1] Grégoire V, et al. "Image guidance in radiation therapy for better cure of cancer" 2020. [2] Kilburn JM, et al. "Image guided radiation therapy" 2016. [3] Siewerdsen JH, et al. "Cone-Beam CT Systems" 2020. [4] Xu, S. "Volumetric computed tomography with carbon nanotube X-ray source array for improved image quality and accuracy" 2023.