MACHINE LEARNING METHODS FOR REAL-TIME MRI IMAGE PROCESSING: MRI-ONLY RADIATION TREATMENT PLANNING AND IMPROVING MR IMAGE RESOLUTION

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Technology Description

A team of researchers at Washington University School of Medicine developed deep learning image processing techniques to improve MRI diagnostics and potentially enable faster, more precise MRI-guided radiation therapy without exposing patients to radiation from CT imaging. Specifically, these methods can: a) estimate CT-equivalent images from MRI scans (and vice versa); and b) de-noise and enhance low resolution MRI images to reconstruct "super resolution" MR images with fourfold enhanced spatial resolution.

Currently, MRI-guided radiation therapy (MRI-guided RT) requires an initial CT scan for dose calculation in treatment planning as well as daily MRIs to provide real-time target tracking and positioning information. However, the CT exposes the patient to harmful ionizing radiation and the daily MRIs do not allow enough acquisition time to obtain a high resolution image of moving organs. This machine learning technology solves those problems using a toolkit of generative adversarial network (GAN) methods to either generate a "synthetic CT" (sCT) from an MRI image or to reconstruct a "super resolution" MRI image from a fast, low resolution scan. In a diagnostic setting the sCT technology could be used to convert either CT images to MRI or MRI images to CT in settings where both modalities are not readily available. The sCT technology could also provide a first step toward an MRI-only radiation therapy that enables widespread clinical application of MR-guided RT. Furthermore, the robust, super resolution reconstruction technology could improve MR-guided RT by providing an end-to-end method for producing detail-preserving images from noisy scans in a clinically feasible timer frame, including 3D breath-hold MRI and 4D-MR.

Stage of Research

- **Estimating CT from MRI –** Using over 1000 test images the inventors demonstrated that this new GAN architecture (deep spatial pyramid convolutional framework) significantly reduced training time and improved in image quality at every training data set size compared with the conventional framework (U-net architecture). In addition, performance of the sCT scans were comparable to clinical plans.
- **Super resolution MRI** – Using a training set with matched pairs of low resolution and high resolution images, the inventors generated super resolution images with fourfold enhancement in spatial resolution over the original low resolution images

Applications

- **Radiation therapy** – treatment planning, motion management and target delineation for MRI-guided radiation therapy (MRI-guided RT)
- **Diagnostic imaging:**
  - MRI super resolution and post processing to provide more precise diagnosis with fast-scanned low resolution images
  - Estimate CT from MRI to provide information on bony anatomy without radiation exposure
  - Estimate MRI from CT to provide soft tissue images when MRI is unavailable

Key Advantages of MRI-only Workflow (sCT)

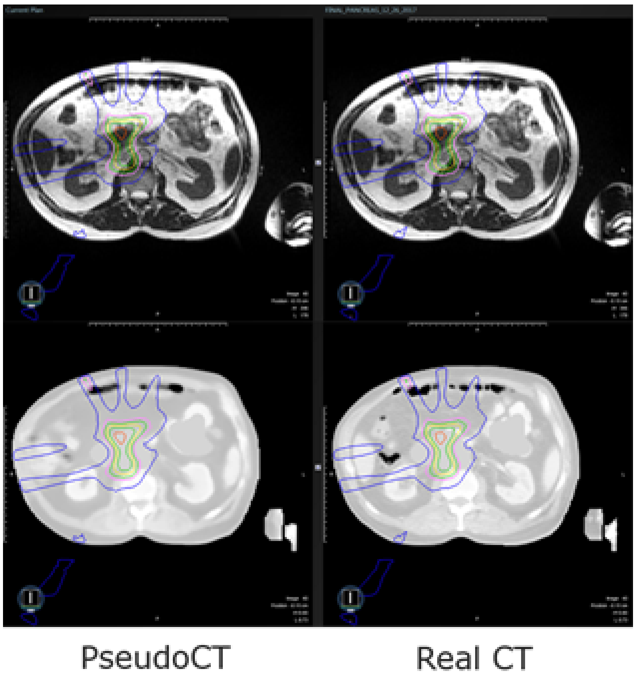
- **Reduced radiation exposure** because no CT scan needed
- **Real-time target tracking and dosage adjustments –** routine daily MRI can be converted to sCT to provide density information and adapt to daily changes in patient anatomy and positioning during MRI-guided RT
- **Improved accuracy and efficiency –** potential to:
  - eliminate image registration errors from combining MRI with CT
  - reduce clinical workload and improve efficiency for MRI-guided RT

Key Advantages of Super Resolution MRI

- **Fast acquisition time –** minimizes scanning time while maximizing spatial resolution
  - real-time 4D image generation with ultrafast low resolution MR and front-end de-noising
  - easier to delineate moving organs in reconstructed high resolution 3D MRI
  - more patients can be treated per day
- **Improved target tracking during MRI-guided RT**
- **High quality training data –** training set has matched pairs of low resolution and high resolution images

Sample Images

Conversion of MRI image to synthetic CT ("PsuedoCT") image



Super Resolution MRI

SR Output 1.5 x 1.5mm (left) vs. Real-time 4D-MRI 6.0 x 6.0 mm (right)

Publications

- Olberg, S., Zhang, H., Kennedy, W. R., Chun, J., Rodriguez, V., Zoberi, I., ... & Park, J. C. (2019). Synthetic CT reconstruction using a deep spatial pyramid convolutional framework for MR‐only breast radiotherapy. *Medical physics*, 46(9), 4135-4147.
- Chun, J., Zhang, H., Gach, H. M., Olberg, S., Mazur, T., Green, O., ... & Park, J. C. (2019). MRI super‐resolution reconstruction for MRI‐guided adaptive radiotherapy using cascaded deep learning: In the presence of limited training data and unknown translation model. *Medical physics*, 46(9), 4148-4164.

Patents - Patent Application Pending