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Deep Learning Framework for Sparse Tomographic Image Reconstruction

Researchers at Stanford have developed a methodology for deep learning-based image reconstruction by incorporating the physics or geometry priors of the imaging system with deep neural networks. This invention may be implemented in different imaging modalities such as MRI and CT. The researchers are the first to investigate the problem of volumetric MRI using ultra-sparse k-space samples that can be acquired within a second. Their physics-aware deep learning framework is able to reconstruct high quality MRI from sparse k-space samples, and they have validated the proposed approach across various abdominal patients. For CT applications, the researchers have investigated the novel-view projection synthesis problem for X-ray imaging. Their approach can also be generalized to a more general synthesis from multi-views to multi-view projections. Their solution provides a deep learning-based geometry-integrated projection synthesis model to generate novel-view X-ray projections through feature disentanglement and geometry transformation. They have validated their approach using X-ray projections across various lung patients.

Applications

- **MRI implementation**
    - **Fast MRI** with significantly reduced acquisition time and cost for simplified hardware design and clinical workflow
    - Generation of volumetric images for **real-time image-guided interventions**, such as image-guided radiotherapy on a MR-Linac system
    - Generation of **high temporal resolution image series** to capture dynamic biological processes, such as diffusion-weighted MRI and dynamic contrast-enhanced MRI for more accurate **disease diagnosis**, **clinical decision making** and **treatment planning**
- **CT implementation**

    - **Streamlined tomographic imaging** with significantly reduced imaging dose and simplified hardware design with substantially reduced efforts in data acquisition
    - Projection image generation for **various clinical applications**, such as image-guided radiation therapy and intervention
    - Generation of **volumetric images** for applications such as treatment planning and dose calculation in **clinical cancer treatment**, **disease diagnosis** and **decision making**

Advantages

- **MRI implementation**
    - This is the **first** work to provide a feasible solution to generate volumetric MRI with sub-second data acquisition time without relying on surrogate signals
    - The proposed physics-aware deep learning framework introduces **a novel strategy** to integrate fixed priors of imaging physics with network-learned features for volumetric MRI reconstruction, which is **more robust** to longitudinal patient changes and **flexible** with different acquisition schemes
- **CT implementation**
    - This work provides a **feasible solution** to synthesize novel-view X-ray projections from a specific view X-ray projection, which can also be generalized to synthesizing multiple projections
    - This geometry-informed deep learning framework for ultra-sparse tomographic image reconstruction introduces a **novel mechanism** for the integration of geometric priors of the imaging system, which is **more robustly generalized** across different patients especially with sparse sampling

Publications

- Liu L, Shen L, Johansson A, Balter JM, Cao Y, Chang D, Xing L. [Real time volumetric MRI for 3D motion tracking via geometry-informed deep learning.] *Med Phys.* 2022 Sep;49(9):6110-6119. doi: 10.1002/mp.15822. Epub 2022 Jul 6. PMID: 35766221.

- Liyue Shen, Wei Zhao, Dante Capaldi, John Pauly, Lei Xing. A geometry-informed deep learning framework for ultra-sparse 3D tomographic image reconstruction. *Computers in Biology and Medicine,* Volume 148, 2022.
- Shen, Liyue, et al. "A Geometry-Informed Deep Learning Framework for Ultra-Sparse 3D Tomographic Image Reconstruction." *arXiv preprint arXiv:2105.11692* (2021).
- Shen, L., et al. "Novel-view x-ray projection synthesis through geometry-integrated deep learning." *International Journal of Radiation Oncology, Biology, Physics* 111.3 (2021): e118-e119.

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