Research Proposal on Brightness-Sensitive Cascaded Generative Network for PET-to-CT Generation Method

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1 Background

Positron emission tomography (PET) and computed tomography (CT) imaging delivers metabolic and anatomical information; however, the PET/CT scanners in a single examination are expensive, entail a relatively high radiation dose, and are seldom available in resource-limited settings. In recent years, generative adversarial networks (GANs) [**?**] have shown strong promise for cross-modal medical-image translation, yet prevailing methods still exhibit blurred textures, intensity distortions in high-brightness regions, and overall performance plateaus. To address these limitations, we propose a *Brightness sensitive cascaded GAN* that exploits a cascaded encoder–decoder chain extension framework together with a brightness-sensitive loss to enhance CT-to-PET synthesis. The study systematically explores how multi-stage generation and brightness-adaptive constraints contribute to clinically usable pseudo-PET images, providing a technical basis for low-cost early screening.

2 Objectives

Theoretical. Develop an interpretable cross-modal cascaded generation framework and elucidate how multi-stage decomposition and brightness-sensitive loss jointly improve structural and textural fidelity.

Algorithmic. Design and optimise multi-cascade generators, multi-scale luminosity modelling, and adaptive weight-scheduling strategies to better reconstruct both hyper- and hypo-intense details.

Applied. Validate the model's robustness and transferability on multi-centre public and clinical brain PET/CT cohorts, assessing its auxiliary value in early stroke screening, tumour quantification, and prodromal Alzheimer's disease detection.

3 Method

3.1 Dataset

This work employs the lung PET/CT dataset from the National Cancer Institute's Cancer Imaging Program (CIP)[**?**], comprising 251,135 DICOM images from 355 patients, along with metadata such as sex, age, body weight, smoking history, and diagnostic category. Tumour sub-types are annotated as adenocarcinoma (A), small-cell carcinoma (B), large-cell carcinoma (E), and squamous-cell carcinoma (G). Because only a subset underwent both modalities, we selected 38 patients with type B small-cell carcinoma, each providing paired PET and CT scans and contrast-enhanced images, for a total of 464 aligned PET/CT pairs. All data were anonymised and resampled to RGB 256×256.

3.2 Method Optimisation

To overcome current limitations, we investigate more efficient architectures and training paradigms for cross-modal conversion:

1. Building on DSGGAN[**?**] or U-Net[**?**] like methods, we tailor generator and discriminator designs to medical-image translation tasks.
2. Cascaded extension framework and attention mechanisms are incorporated to focus the network on salient anatomical structures.
3. Composite loss functions that blend perceptual and adversarial terms are explored to enhance visual realism and structural similarity.
4. Multi-task and transfer-learning strategies are adopted to strengthen generalisation and accelerate convergence.

4 Innovations

1. **Stage-wise of multi-stage extension learnability:** A cascaded generator is analysed to harness its benefits while mitigating the over-fitting that indiscriminate stacking can cause.
2. **Multi-scale brightness sensitive function:** We introduce brightness masks with adaptive weights to restore both high-density cortical bone and low-density parenchymal textures.

5 Expected Outcomes

Algorithmic. A high-performance luminosity-aware cascaded GAN framework and a reproducible data-pre-processing pipeline.

Scholarly. Submission of at least two papers to venues such as *JACIII* or *IEEE TMI*, or filing of one Japanese invention patent.

References

[1] Alec Radford, Luke Metz, and Soumith Chintala. Unsupervised Representation Learning with Deep Convolutional Generative Adversarial Networks, 2015. Version Number: 2.

[2] Ping Li, Shuo Wang, Tang Li, Jingfeng Lu, Yunxin HuangFu, and Dongxue Wang. A Large-Scale CT and PET/CT Dataset for Lung Cancer Diagnosis, 2020.

[3] Huabin Wang, Xiangdong Wang, Fei Liu, Grace Zhang, Gong Zhang, Qiang Zhang, and Michael L. Lang. DSG-GAN:A dual-stage-generator-based GAN for cross-modality synthesis from PET to CT. *Computers in Biology and Medicine*, 172:108296, April 2024.

[4] Olaf Ronneberger, Philipp Fischer, and Thomas Brox. U-Net: Convolutional Networks for Biomedical Image Segmentation. In Nassir Navab, Joachim Hornegger, William M. Wells, and Alejandro F. Frangi, editors, *Medical Image Computing and Computer-Assisted Intervention – MICCAI 2015*, volume 9351, pages 234–241. Springer International Publishing, Cham, 2015. Series Title: Lecture Notes in Computer Science.