Washington University in St. Louis
Office of Technology Management

AUTOMATED IMAGE PROCESSING TOOLS FOR QUANTITATIVE SPECT AND PET SCANS

Jha, Abhinav Kumar, Liu, Ziping, Moon, Hae Sol, Rahman, Md Ashequr, Yu, Zitong

Markiewicz, Gregory

T-019331

Engineers in Washington University's Computational Medical Imaging Lab have developed automated, machine-learning techniques to improve nuclear medicine imaging (SPECT and PET). These tools include estimation-based segmentation methods to define boundaries and ASC (attenuation and scatter compensation) methods that improve sensitivity without needing CT transmission.

Spatial resolution in PET and SPECT images can be limited by partial volume effects (PVE) that arise from blur and tissue fraction effects (TFE). Furthermore, low resolution scatter and the resultant attenuation and noise can degrade images, leading to quantification errors. It is important to compensate for these artifacts, particularly in small regions located deep in the brain. This technology includes several physics-guided tools that address these problems.

The first tool uses an automated estimation-based segmentation method with a learning architecture to account for PVEs in low resolution images. It provides a continuous estimate of tissue fraction area within each pixel or voxel. In addition, it is faster, lower-cost and less variable than manual delineation. It has been demonstrated on 2D PET scans to identify tumor boundaries and on 3D SPECT/ dopamine-transporter (DaT)-scan SPECT to define multiple small brain regions affected by Parkinson's disease (caudate, putamen, and globus pallidus).

The second tool utilizes the entire SPECT emission data in list mode format (the scatter window along with the conventional photopeak window) for rigorous attenuation and scatter compensation (ASC). By including photons from the scatter window, this technique increases the number of photons available to perform reconstruction, thereby improving sensitivity. Furthermore, the method does not require a CT transmission scan, thus reducing time and radiation exposure to the patient. This ASC technique can enable reliable SPECT quantification for end-user applications such as quantifying biomarkers or dosimetry analysis.

Stage of Research

Proof-of-principle in highly clinically realistic simulation studies:

- Estimation-based segmentation method:
  - significantly out-performed several conventional methods (including U-net-based methods)
  - improved qualitative and quantitative accuracy of PET (non-small cell lung cancer) and SPECT (DaT-scan with accurate boundaries of small brain structures)
  - demonstrated reliable performance for different clinical configurations
- ASC methods:
  - improved quantification of DaT-scan SPECT (compared with using photopeak window only or using binned data)
  - demonstrated performance equivalent to ASC techniques that use transmission scans - validated on quantitative and diagnostic tasks for DaT-scan SPECT and myocardial perfusion SPECT, respectively

Applications

- **Nuclear medicine image processing** with end-user applications such as:
    - PET-based radiotherapy planning and quantification of radiometric and volumetric features (e.g., tumor segmentation and estimating tumor fraction area)
    - DaT-scan SPECT to diagnosis and assess severity in Parkinson's disease
    - SPECT for coronary artery disease

Key Advantages

- **Faster, quantitatively accurate results with fully automated segmentation**:
    - no inter- and intra-reader variability
    - accounts for both sources of PVEs (blur and tissue fraction effects)
    - sub-voxel resolution provides for PVE with more accurate boundaries even in small structures
    - segments globus pallidus in DaTscan SPECT images, a region that is almost impossible to segment manually and for which, no computer-aided tools are available
- **Improved image resolution with attenuation and scatter compensation**:
    - enhances effectiveness of quantification and visual interpretation
    - breaks conventional sensitivity limits for precise regional quantification (e.g., globus pallidus and substantia nigra in brain)
    - no transmission scan needed – eliminates radiation from CT scan and reduces risk of misalignment from different modalities

Publications:

- Liu, Z., Laforest, R., Mhlanga, J., Moon, H. S., Fraum, T. J., Itani, M., ... & Jha, A. K. (2020). An estimation-based method to segment PET images. arXiv preprint arXiv:2003.00317.
- Rahman, M. A., Zhu, Y., Clarkson, E. W., Kupinski, M. A., Frey, E. C., & Jha, A. K. (2020). Fisher information analysis of list-mode SPECT emission data for joint estimation of activity and attenuation distribution. *Inverse Problems*.
- Leung, K. H., Marashdeh, W., Wray, R., Ashrafinia, S., Pomper, M. G., Rahmim, A., & Jha, A. K. (2020). A physics-guided modular deep-learning based automated framework for tumor segmentation in PET. *Physics in Medicine & Biology*.
- Rahman, M. A., Laforest, R., & Jha, A. K. (2020, April). A List-Mode OSEM-Based Attenuation and Scatter Compensation Method for SPECT. In *2020 IEEE 17th International Symposium on Biomedical Imaging (ISBI)* (pp. 646-650). IEEE.
- Moon, H. S., Liu, Z., Ponisio, M., Laforest, R., & Jha, A. (2020). A physics-guided and learning-based estimation method for segmenting 3D DaT-Scan SPECT images. *Journal of Nuclear Medicine*, 61(supplement 1), 10-10.
- Liu, Z., Laforest, R., Moon, H. S., Mhlanga, J., Fraum, T., Itani, M., ... & Jha, A. (2020). An estimation-based segmentation method to delineate tumors in PET images. *Journal of Nuclear Medicine*, 61(supplement 1), 447-447.

Patents: Application pending

Related Web Links: Computational Medical Imaging (CMI) Lab