Recipes for improving image quality reduces radiation doses

CoSeC
Computational Science Centre for Research Communities

Dr Palak Wadhwa formerly of the University of Leeds and Invicro (London), and funded partly through an exchange program organized by the Collaborative Computational Project for Synergistic Image Reconstruction for Biomedical Imaging (CCP SyneRBI), wrote the joint-3rd placed winning entry for the 2021 CoSeC Impact Award. Palak's research made a significant addition to medical imaging software that contributed to the combination of two scanning methods that reduces the dose of radiation received from repeated scans. Ultimately, this could lead to an increase in the early diagnosis of diseases in vulnerable patient groups including pregnant women and babies.

Background

The use of positron emission tomography /computerized tomography (PET/CT) scanning techniques (a.k.a. modalities) for diagnosis and patient management can reduce the mortality of cancer patients.

PET scanners detect photons that are transmitted through tissue, and register them as raw data. Using reconstruction algorithms this raw data is converted into an image that represents the uptake of radioactive material.

PET is a highly sensitive and specific imaging modality and has proven to be very successful in disease diagnosis and patient management particularly within oncology, neurology and cardiology. Its main drawback is that each scan provides a substantially high radiation dose that could increase the risk of cancer.

This implies that babies, young adults and pregnant women should not be scanned using PET/CT for cancer, and diseases of the nervous system and heart. This problem can be resolved by combining PET with magnetic resonance imaging (PET/MR), providing the high sensitivity of PET with the soft tissue contrast from MR, although the images often suffer from noise.

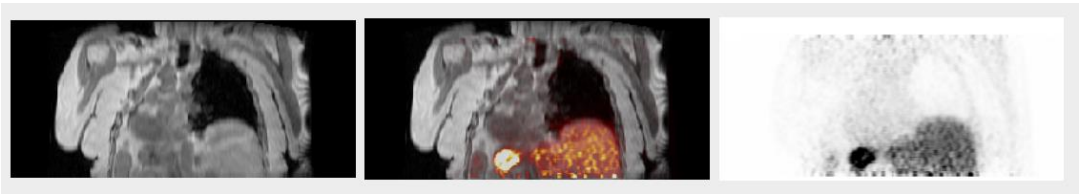
CCP SyneRBI developed an open-source software platform called synergistic image reconstruction Framework (SIRF). This platform is a single-point access to a range of algorithms that includes image noise reduction. The format of the platform is highly beneficial to increasing the efficiency of research and development in the field of biomedical imaging, enabling researchers to overcome diverse challenges.

Challenges

PET/MR scans can reduce the radiation dose up to 70% over PET/CT scans, but the scanners are 100 times more expensive; currently there are only 10 in the UK. PET/CT scanners have been highly successful as the CT anatomical images help improve PET images by providing noise-reduction maps. This success was not translated to PET/MR due to the lack of direct noise-reduction maps, as well as the high costs of the scanner. To further reduce image noise and increase the detected radiation uptake, faster electronics have been incorporated in state-of-the-art time-of-flight (TOF) PET scanners. This increased timing resolution improves signal-to-noise and contrast-to-noise ratio in the images. **To realize the full potential of PET/MR scanners and their advantages over PET/CT scanners, they need to demonstrate higher image quality; this depends on the availability of the image reconstruction algorithms to build noise-reduction maps, and to fully exploit the TOF feature.**

Your role in addressing the challenges

Dr. Wadhwa's research built on the computational collaborative effort of SIRF, focusing on developing an open-source software framework that would allow its users to reconstruct the TOF PET data extracted from the PET/MR scanner. The developed software is equipped with classes and utilities necessary to read the raw data outputs from the (GE SIGNA) PET/MR scanner to calculate the emission and data-correction required to produce representative visualizations. The calculated emission and data correction can be used to reconstruct PET images using any image reconstruction algorithm available within SIRF. The developed software platform is also robust and has demonstrated the potential to reconstruct PET data from other (GE) scanners.
Palak's research further expanded towards a novel image reconstruction algorithm called TOF-kernelised expectation algorithm (TOF-KEM), which took the aforementioned developments one step further. This image reconstruction used MR anatomical images to guide PET reconstruction, thereby substantially reducing image noise and slightly improving image analysis.
Dr. Wadhwa's algorithmic contributions are steps towards establishing the advantages of a PET/MR scanner. The algorithms have demonstrated the potential to reduce the injected dose of radiation by a factor of 10, without loss of image quality. Ultimately, the reduced radiation dosage will enable the early diagnosis of diseases in vulnerable patient groups such as babies, young adults and pregnant women.



Left: MR anatomical image used to compute MR kernel; middle: fused reconstructed PET image and MR image; right: PET image reconstructed using TOF-KEM algorithm implemented within SIRF. (Figure taken from thesis: Wadhwa, 'Anatomically informed image reconstruction for time of flight positron emission tomography.' PhD thesis, University of Leeds. Figure used under the terms of Creative Commons Attribution Non-commercial Share Alike (v4).)

CoSeC's Impact

> CoSeC-supported CCPs provided the main software platform for my research developments. The workshops and hackathons organised by CCP SyneRBI provided an excellent platform for discussion and development of the research software.
>
> Dr. Palak Wadhwa

CCP SyneRBI is the successor of CCP PETMR, and is extending its scope to other multi-modal biomedical imaging systems. Its primary aims are:

- Networking and community building
- Bringing together expertise
- Training the next generation
- Expanding open source software infrastructure
- Translating towards biomedical research

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Funding: This research was funded by a Medical Research Council Industrial CASE PhD Scholarship (MR/M01746X/1) and Invicro (Imanova Bursary). CCP PET MR Exchange Programme Grant was also awarded as a part of this work to incorporate the implementations made in open-source software, Software for Tomographic Image Reconstruction (STIR) and Synergistic Image Reconstruction Framework (SIRF).
Further information: Dr. Wadhwa was a PhD student (University of Leeds) at the time of completing this research and entering the call for the 2021 CoSeC Impact Award.

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