Validation of CT-free Template-Based Attenuation Correction in Brain PET Imaging

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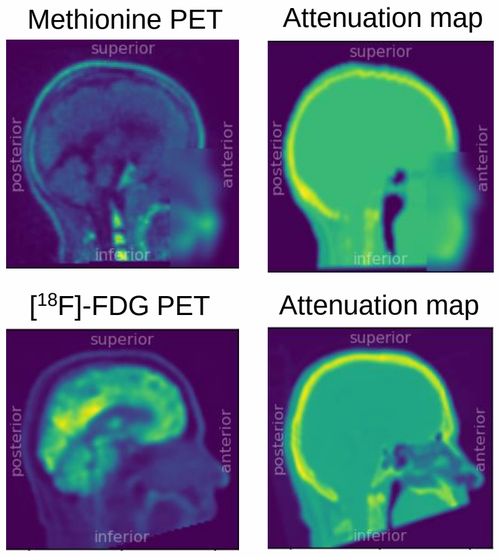
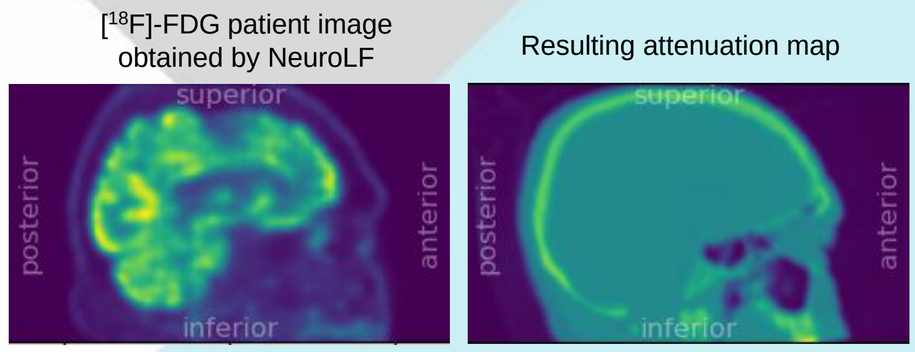
Background: Template-based Attenuation Correction Method for PET-only Brain Scanners [1]

NeuroLF Brain PET Device

Examples of templates for different PET tracers:



Affine registration using nifty-reg [2]



- How reliable is the template registration?
- How large are the errors introduced by a generic template?
- Is one tracer more challenging?

Methods: Validation of Template-based Attenuation Correction for Common Brain Tracers

Inputs:

- 103 reference patients
- 193 reference brain scans (PET/MR)
- Tracers:
  - [18F]-FDG
  - [18F]-FBB (Amyloid)
  - [11C]-PIB (Amyloid)
  - [18F]-PI2620 (Tau)
  - [11C]-Methionine
- 4 templates (PET/CT pairs from other patients) for uncorrection (***tmpl. A***)
- 4 templates for validation (***tmpl. B***)

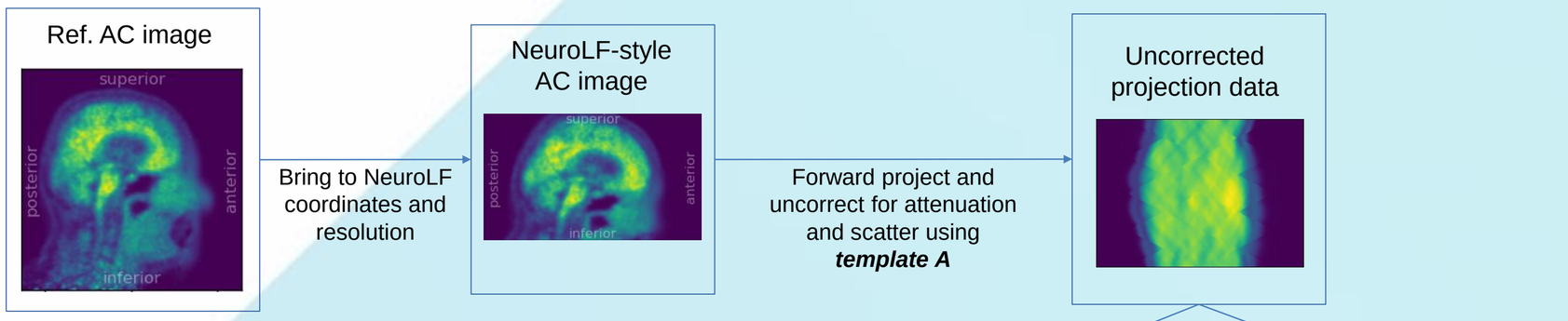


Image Comparison:

Mask the brain to exclude skull, skin and air cavities:

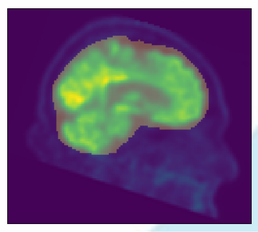
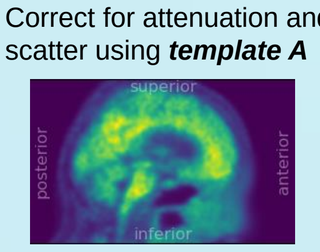


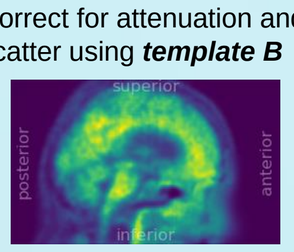
Image metrics applied between reconstructed images and the NeuroLF-style AC reference image:

- Norm. root mean square error (NRMSE) [3]
- Structural similarity (SSIM) [4]
- Peak signal-to-noise ratio (PSNR) [5]
- Normalised cross-correlation (NCC) [6]

Reconstruction #1:
Correct for attenuation and scatter using ***template A***

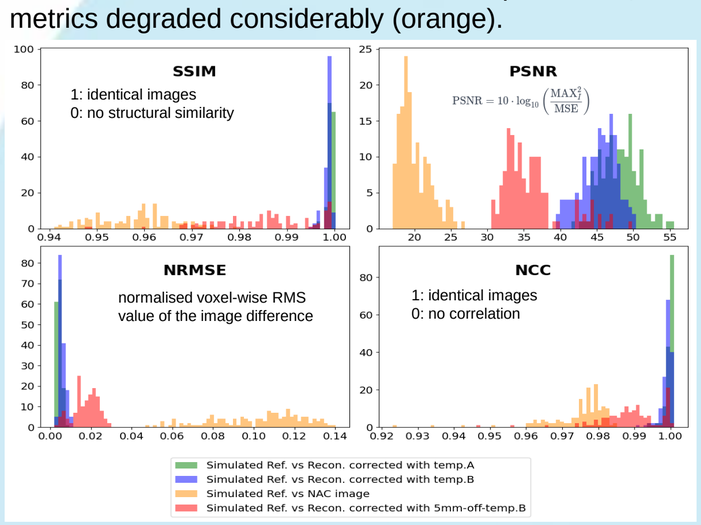


Reconstruction #2:
Correct for attenuation and scatter using ***template B***

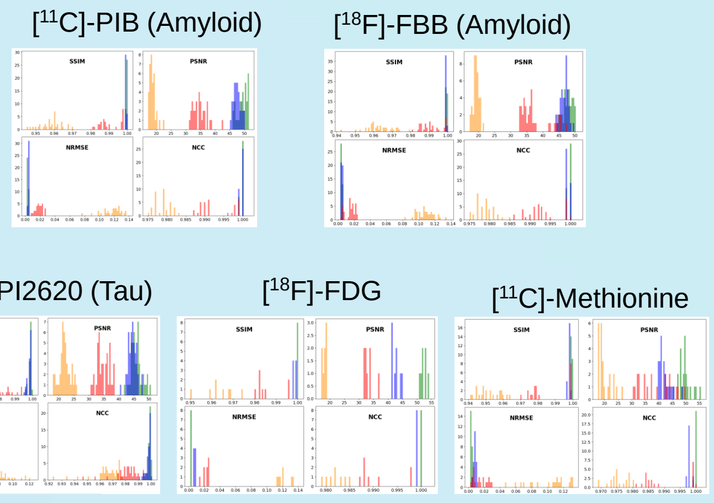


Results:

The differences between reconstructions with the correct template A (green) and another template B (blue) were very small. To illustrate the impact of a wrong attenuation correction on the metrics, template B was shifted by 5 mm laterally (red). Similarly, when no attenuation and scatter correction was performed, the metrics degraded considerably (orange).



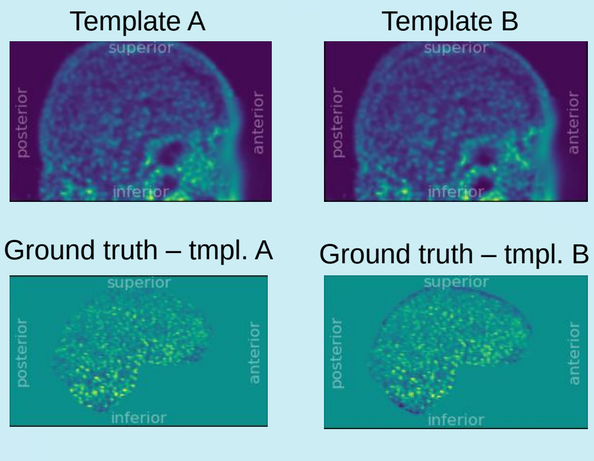
There was more variance in the cases of FDG and Methionine, whereas Tau and Amyloid tracer images had the most similar metrics when comparing the correct template A (green) and a generic template B (blue).



Example images for a case with some of the largest differences in metrics between correct and generic template (Tau tracer).

The metrics were:

SSIM = 0.996 PSNR = 43.705
NRMSE = 0.007 NCC = 0.994



Conclusions:

- No cases were found where the registration of the template to the uncorrected image failed. Worst cases would be when a patient is inadequately placed in the scanner head, which was not looked at this study but should be tested.
- The errors introduced by a generic attenuation template were visually undiscernible and impacted the image quality metrics only marginally.
- The metrics varied most widely for FDG and Methionine tracers. This could either mean that registration is more challenging for these or that certain metrics (such as PSNR) are more sensitive to the distribution of the different tracers.
- The used metrics only work if a reference image is available. For detecting mis-registered attenuation maps in clinical practice a visual inspection is currently required.

Discussion:

- To best cover the range of possible head geometries, having a selection of different templates per tracer would enable the choice of the most appropriate one for use for each individual case. How this choice is made will need to be investigated.
- For pediatric patients the used templates may not be appropriate, due to potentially different skull density or shape.

Acknowledgments:

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