Data-driven motion detection and correction for brain PET

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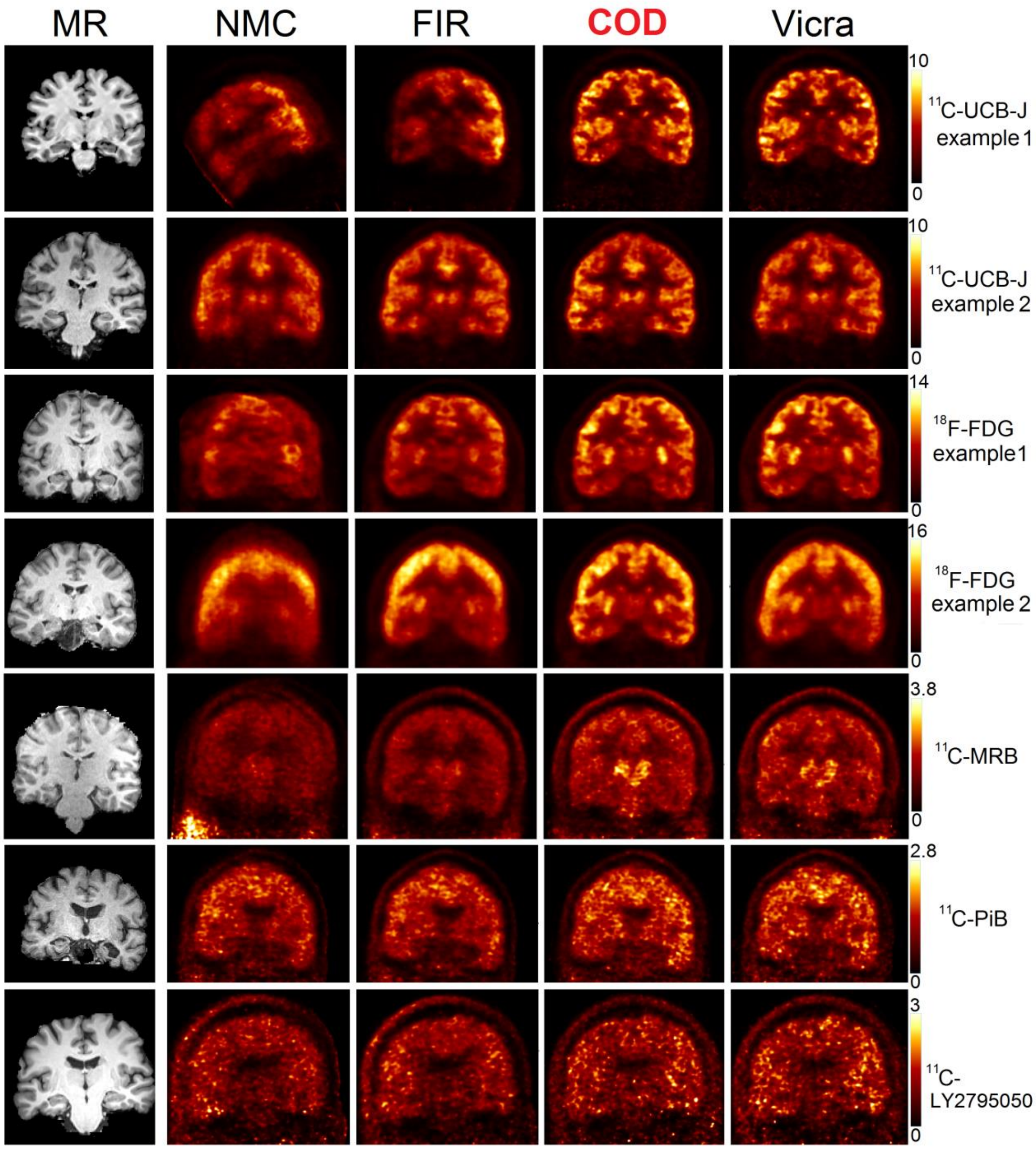
Objectives: Existing brain PET motion correction (MC) methods include frame-based image-registration (FIR) and correction using real-time hardware-based motion tracking (HMT) information. FIR cannot correct for motion within one scan period (intra-frame) while HMT is not routinely used clinically, since it requires attaching a tracking device to the patient. Thus, there is a need to develop a robust data-driven approach, based on PET data, to detect and correct head motion. Here, we developed a data-driven approach to detect and correct head motion in an event-by-event fashion. The proposed approach was compared to FIR and HMT with the Vicra, an optical motion tracking device.

Methods: We use Centroid-Of-Distribution (COD) [1], a data-driven approach, to detect head motion with 1-second temporal resolution followed by event-by-event motion compensated reconstruction [2]. In this approach, the central (X,Y,Z) coordinates of the line of response (LOR) of all events are averaged over 1-sec intervals to generate a COD trace. The trace was smoothed by a median filter. A point-to-point change in the smoothed trace that exceeded a user-defined threshold was defined as a time point of subject motion. Short periods containing frequent motions (e.g., >2 times/20sec) were excluded from further processing. We reconstructed all the frames separated by such time points with minimal intra-frame motion without attenuation correction (denoted as “motion-free” frames [3]). The PET “motion-free” frame closest to the transmission scan in time was chosen as the reference frame. Subsequent frames were then rigidly registered to the reference frame. The resulting transformation matrices and the PET list-mode data were then used by MOLAR to perform the final event-by-event motion compensated reconstruction. Using motion data from the Vicra, HRRT scans from 23 subjects with medium-to-large motion (top 20% of 836 cases based on Vicra data) were selected for evaluation. These subjects came from multiple diagnostic categories and were scanned with 5 different tracers (11 ^{11}C-UCB-J, 9 ^{18}F-FDG, 1 ^{11}C-MRB, 1 ^{11}C-PiB, and 1 ^{11}C-LY2795050). Using the AAL template and individual MR images, 10 gray matter (GM) regions of interest (ROIs) were applied to 45-90min SUV images: frontal, occipital, parietal, temporal cortices, hippocampus, cerebellum, caudate, pulvinar, putamen, and thalamus. The COD-based approach was compared to no MC (NMC), FIR (5min/frame), and Vicra, which was considered as the gold standard.

Results: The averaged bias (compared to Vicra) in SUV across all tracers and all ROIs were: **-11.6% (inter-subject SD 8.8%) for NMC, -8.1% (8.2%) for FIR and 0.6% (2.4%) for COD**. Note that the slight positive bias for COD may be a real improvement since Vicra-to-patient attachment may not remain rigid at all times, especially with large, rapid motion. For 4 cases, visual assessment showed that COD yielded superior MC results compared to the Vicra in terms of image resolution. Regional bias results across all tracers are shown in the table. Averaged % bias results (NMC, FIR, COD) for each tracer were: ^{11}C-UCB-J: -7.5%, -4.5%, 1.1%; ^{18}F-FDG: -13.5%, -9.3%, 0.1%; ^{11}C-MRB: -31.4%, -23.6%, 2.7%; ^{11}C-PiB: -13.9%, -14.0%, -0.2%; ^{11}C-LY2795050: -17.6%, -14.6%, -0.6%.



Comparison among different motion correction methods. All PET images are 45-90min SUV. Blurring in VC example 2 of UCB-J and example 2 of FDG show certain Vicra-attachement issues happened during the scans.

NMC: without motion correction
FIR: frame-based image-registration
COD: centroid of distribution (data-driven)
Vicra: Polaris-Vicra motion tracking device

ROIs	NMC	FIR	COD
Frontal	-13.2%	-7.4%	1.2%
Occipital	-11.9%	-6.5%	0.7%
Parietal	-5.6%	-7.0%	0.0%
Temporal	-11.4%	-6.0%	0.6%
Hippocampus	-9.0%	-8.2%	1.7%
Cerebellum	-9.5%	-6.2%	1.0%
Caudate	-12.2%	-8.8%	1.2%
Pulvinar	-17.8%	-12.2%	0.1%
Putamen	-10.1%	-7.5%	-0.1%
Thalamus	-15.5%	-10.6%	0.1%

Conclusions: The proposed COD-based data-driven head motion detection and correction outperformed FIR and achieved comparable or better performance to the Vicra motion tracking method for multiple tracers. Further exploration will include 1) performance comparison for kinetic modeling, 2) more tracers, 3) more and smaller ROIs and 4) more subjects, and 5) assessment of noise effects.

References: [1] Ren et al., PMB, 2017. [2] Jin, et al., Med Phys, 2013. [3] Picard et al., TMI, 1997.