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4-D PET joint image reconstruction/non-rigid motion estimation with limited MRI prior information

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Motion compensated gated PET image reconstruction methods include joint-reconstruction (JR) and indirect reconstruction (IR) with pre-estimated motion from MRI (MRI-IR). JR suffers from poor PET data quality whereas MRI-IR requires high-quality MRI volumes at each gate. We propose a penalised maximum-likelihood approach combining JR and MRI-IR. Our method is referred to as *minimal MRI prior* JR (MP-JR).

The M gates data are stored in $\boldsymbol{g} = [\boldsymbol{g}_1; \ldots; \boldsymbol{g}_M]$ where $\boldsymbol{g}_m$ is the measurement vector at gate m. Each $\boldsymbol{g}_m$ is a Poisson distributed vector of parameter $\bar{\mathrm{g}}(\mathrm{f},\alpha_m) = \mathrm{P}W(\alpha_m)\mathrm{f} + \mathrm{r}_m$ where $\boldsymbol{P}$ is the projector, $W(\boldsymbol{\alpha}_m)$ is the m-th motion of parameter $\boldsymbol{\alpha}_m$, $\boldsymbol{r}_m$ is the m-th average random/scatter vector and $\boldsymbol{f}$ is the activity at $m = 1$. JR is achieved with (1).

$$\text{minimise } L(\mathrm{f},\alpha) = -\sum_{m=1}^{M}\sum_{i=1}^{I} g_{i,m}\log\bar{g}_i(\mathrm{f},\alpha_m) + \bar{g}_i(\mathrm{f},\alpha_m) \text{ w.r.t. } \mathrm{f},\alpha \tag{1}$$

MRI-IR is achieved by solving (2)

$$\text{minimise } L\left(\mathrm{f},\alpha^{mri}\right) \text{ w.r.t. } \mathrm{f} \tag{2}$$

MP-JR is achieved with (3).

$$\text{minimise } L(\mathrm{f},\alpha) + \beta\sum_{\ell\in\mathcal{S}}\left\|\alpha_\ell - \alpha_\ell^{mri}\right\|_2^2 + \gamma\sum_{m=1}^{M-1}\|\alpha_{m+1} - \alpha_m\|_2^2 \tag{3}$$

The first term accounts for PET data, whereas the second term accounts for MRI motion information from subset S. The last term controls temporal smoothness.

We tested each method on 9 PET FDG volumes generated from a real dynamic MRI sequence. Tumours were added to the activity distribution (invisible in the MRI). The gates subset S for MP-JR contains the reference gate, end-inspiration and end-expiration. Reconstruction profiles 1 show that MRI-IR improves edges visible in the MRI but degrades the tumours. On the contrary, JR performs well on tumours, but the

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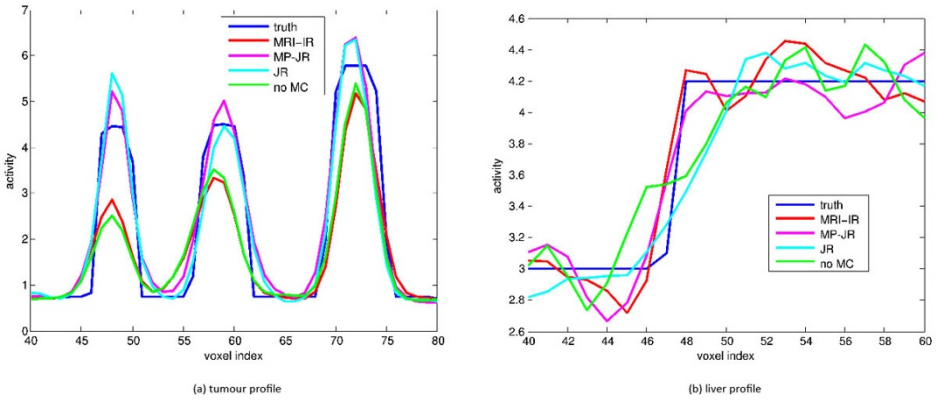

Figure 1 Reconstruction profiles: (a) across tumours; (b) across liver.

edges are poorly reconstructed. MP-JR appears to perform well on both organ edges and tumours.

MP-JR seems to perform well where both JR and MRI-IR under-perform. This is due to the fact that MP-JR relies on both MRI and PET data. In addition, results tend to show that with temporal smoothing on B-spline parameters, a subset of MRI volumes provides sufficient information.

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