Colloquium

Motion and spatial regularization designs in motion-compensated image reconstruction (MCIR): application to simultaneous PET-MR

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Abstract: Often medical imaging systems cannot capture ideal quality images due to their innate acquisition speeds and patient motion. Gating methods have been investigated to reduce motion artifacts, but can suffer from insufficient measurements that result in low SNR images. Motion-compensated image reconstruction (MCIR) methods based on statistical iterative image reconstruction have been studied to improve image quality by using all collected data and motion information so that high SNR images are reconstructed without motion artifacts.

This talk presents two different regularization designs for MCIR. First of all, we investigated methods for motion regularization. The usual choice for a motion regularizer in MCIR has been an elastic regularizer. Recently, there has been much research on regularizing nonrigid deformations with diffeomorphic motion priors. Conventional methods that enforce deformations to be locally invertible require high computational complexity and large memory. We developed a sufficient condition that guarantees the local invertibility of B-spline deformation and proposed a simple regularizer based on that sufficient condition. This motion regularizer was applied to the motion correction using prototype simultaneous PET-MR. We estimated deformable motion from simultaneously acquired tagged MR volumes and incorporated it into the system matrix of unregularized OSEM algorithm for list-mode PET. We demonstrated the improvement of image quality and detection task performance with deformable phantom, rabbit, and small non-human primate studies.

Secondly, we studied the spatial resolution properties of MCIR methods and shows that nonrigid local motion can lead to non-uniform and anisotropic spatial resolution for conventional quadratic regularizers. This undesirable property is akin to the known effects of interactions between heteroscedastic loglikelihoods (e.g. Poisson likelihood) and quadratic regularizers, and can cause non-uniform bias in small or narrow structures such as small lesions or rings of reconstructed images and lead to quantification errors. We proposed novel spatial regularization design methods for three different MCIR methods that account for known nonrigid motion. We develop MCIR regularization designs that provide approximately uniform and isotropic spatial resolution and that match a user-specified target spatial resolution. 2D PET simulations demonstrate the performance and benefits of the proposed spatial regularization design methods.

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