A registration framework based on surface constrained harmonic maps for inter-subject comparisons in small animal PET imaging

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Inter-subject comparisons of Positron Emission Tomography (PET) data in mice can help in better understanding and compare metabolic activities of mice organs in a large scale mice study. Direct PET to PET registrations is particularly challenging due to the limitation of anatomic information caused by the specificity of the tracers. Since we acquire PET/CT data using the same imaging chamber, we can perform an accurate PET/CT registration for a subject and use the CT images to perform inter-subject registrations thus finding indirect PET to PET registrations across subjects.

PET images were registered to CT images using mutual information based rigid registrations. For CT to CT registration, we employ a three stage registration algorithm. As a first stage, we find a one to one map between mice surfaces extracted from CT by a landmark based elastic surface registration method. In order to perform surface registration, we model the surfaces as elastic sheet governed by the associated Cauchy-Navier elastic equilibrium equation. The corresponding 'strain energy' is then minimized to obtain a weak solution to this equation. As a second stage, this surface correspondence is then extrapolated to the entire mouse volume by using 3D harmonic mapping by minimizing the harmonic energy for 3D coordinates. These two steps normalize large scale structural differences in mice volumes by aligning their surfaces accurately. As a third stage, this map is further refined by using an inverse-consistent CT intensity registration. The resulting maps from the three stages are then composed to obtain combined registrations of CT-PET data. This algorithm provides an accurate and powerful framework to analyze group similarities and differences in anatomical and functional CT-PET data, as well as to perform longitudinal studies of such imaging data.