A Registration Framework based on Harmonic Mapping for Inter-subject Comparisons in Small Animal PET/CT Imaging

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Introduction

Inter-subject comparisons of Positron Emission Tomography (PET) data in mice are important for the statistical analysis of multisubject molecular imaging studies. Direct PET to PET registration is particularly challenging due to the limited anatomical information in these images. For studies in which PET/CT data are both acquired, we can instead perform inter-subject registration using the CT images (with contrast). By imaging the mice in a common chamber for both PET and CT a simple rigid registration based on maximizing mutual information is sufficient for the PET to CT alignment. For CT to CT registration, we employ a three stage registration algorithm. The resulting maps from the PET to CT and from CT to CT are then combined to register the two PET volumes. This framework provides a tool for analyzing group similarities and differences in anatomical and functional CT-PET data, as well as longitudinal studies, in which subjects do not need to be accurately positioned with respect to each other.

Inter-subject Registration

- We are interested in registration of two sets of inter-subject data with different modalities, such as PET, CT(optical)
- One set of the data could be a mouse atlas, which can give us additional information after registration.

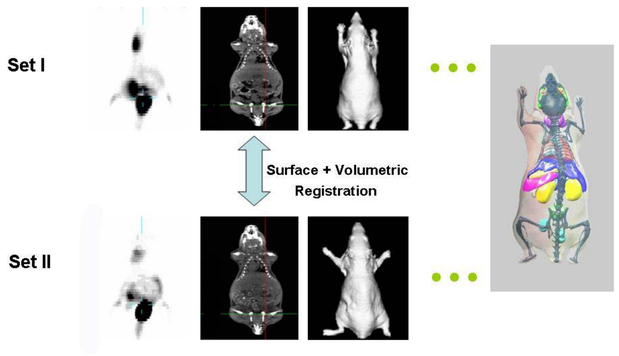

Figure 1: the framework of registing two sets of small animal imaging data, including mouse atlas.

- The following imaging chamber is used so that the mouse can be imaged in microPET, CT and optical scanner. Therefore, for each data set in the above figure, the image registration between different modalities is a easy rigid registration.

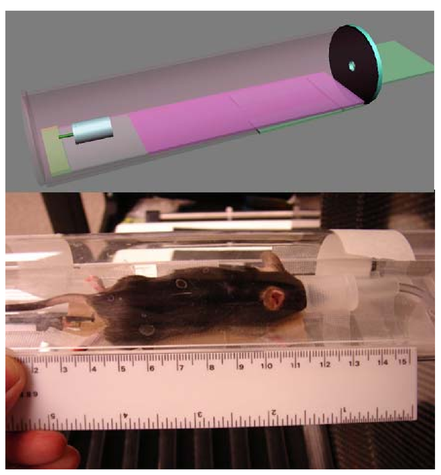

Figure 2: Imaging chamber that is compatible in microPET, CT and optical scanner.

- Then the key is to find a cross subject whole body registration method for mouse study using CT data.

Whole body cross subject CT-CT registration using harmonic mapping

We consider the two mice surface as two Riemannian manifolds: (M, g), (N, h) and try to find a map: $u : M \to N, u \in C^{\infty}(M, N)$.

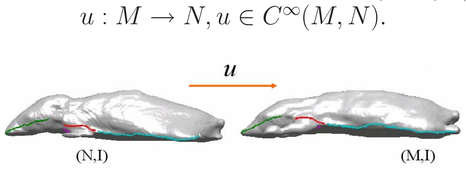

Figure 3: a mapping from Riemannian manifold: (M, g) to Riemannian manifold: (N, h).

- In the first stage, we find a one to one map between mice skin surfaces, automatically extracted from the CT, using a landmark based elastic surface registration method. In order to perform the surface registration, we model the surfaces as elastic sheets governed by the associated Cauchy-Navier elastic equilibrium equation. The corresponding 'strain energy' is then minimized to align the surfaces [1].
- In the second stage, this surface correspondence is then extrapolated to the entire mouse volume using a mapping that minimizes the 3D harmonic energy [2]. These two steps normalize large scale structural differences in mouse volumes by aligning their surfaces and can therefore account for gross differences in the positioning of the two animals, for example by repositioning the limbs of one mouse to match those of the other.

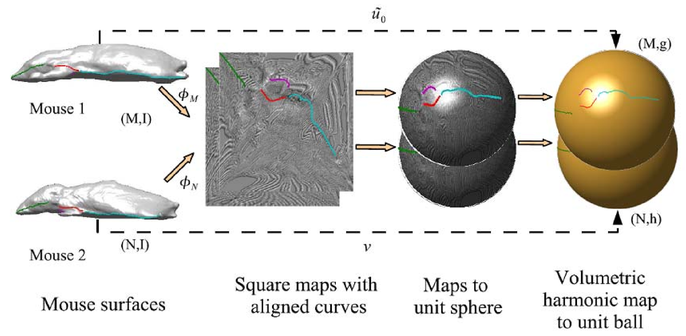

Figure 4: The initialization for the mapping procedure.

- As a third stage, this 3D mapping is refined using an inverse-consistent CT intensity-based registration. The resulting maps from the three stages are then combined to register the two CT volumes.

Result

- We applied the proposed registration method to two sets of dynamic PET/CT data of two mice. The PET scan is a 1 hour FDG scan for breast cancer detection. The registration result is shown in the following figure where the PET and CT data is overlaped for each data set.

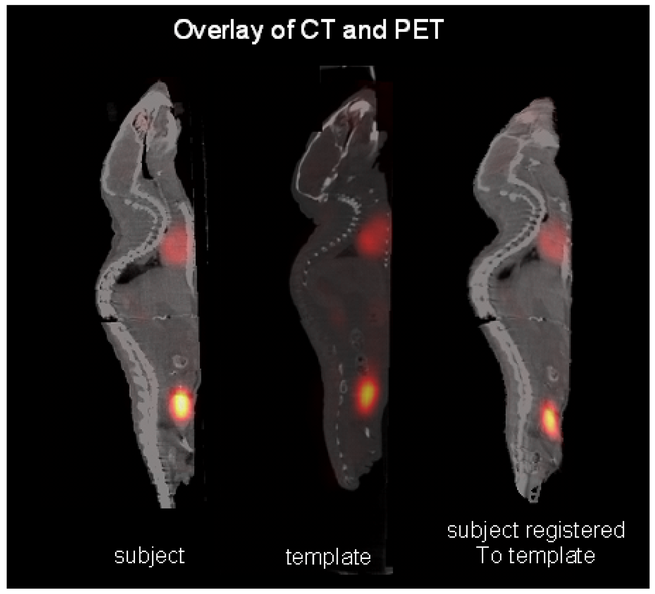

Figure 5: Registration result of two sets of PET/CT data of two mice.

Conclusion

- Simultaneous acquisition of PET and CT scans using imaging chamber results in easily aligned anatomical and functional images.
- We have developed a novel volumetric warping scheme with surface and landmark constraints which registers mouse surface as well as interior anatomical details accurately.
- Application of our registration method could be useful for inter-subject comparisons of PET and CT data and improve the power of subsequent statistical tests.

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References

[1] A. A. Joshi, D. W. Shattuck, P. M. Thompson and R. M. Leahy: *A framework for registration, statistical characterization and classification of cortically constrained functional imaging data*. Lecture Notes in Computer Science. vol. 3565, pp186-196, July 2005.

[2] A. J. Chaudhari, A. A. Joshi, F. Darvas and R. M. Leahy: *A method for atlas-based volumetric registration with surface constraints for optical bioluminescence tomography in small animal imaging*, Proceedings of the SPIE, Vol. 6510, pp. 651024, 2007.