Image Registration and Computational Anatomy in Radiation Therapy

Recent revolutionary advances in the field of medical imaging have facilitated digital imaging modalities such as magnetic resonance (MR), and x-ray computed tomography (CT), are enabling extremely detailed study of anatomy, while development of functional imaging modalities such as functional MRI (FMRI) , positron emission tomography (PET) and single photon emission tomography (SPECT), to mention a few are providing detailed {\it in vivo} information regarding the physiological function. Although the study of anatomical variability can be traced back to the beginnings of modern science, the exquisite resolution and the 3-D and 4-D capabilities of these imaging modalities, combined with the advances in digital computation, is only now enabling the detailed and precise *computational* study of the awesome biological variability of anatomy. This is emerging as the exciting new field of *computational anatomy.* One of the major developments in computational anatomy has been the development of image registration algorithms mapping various imaged anatomies to one another.

The most straightforward methods of registration assume that the images being matched are highly similar for which the variability of only global course features are accommodated via rigid transformations. Other image registration methods, however, are interested in accounting for very local variability across disparate anatomies, thereby requiring high-dimensional transformations, the dimension of which are proportional to the number of voxels in the volume. A number of investigators have taken the approach in which the mapping is based on geometric features, such as landmarks (points) and contours (lines) . Alternatively, others have investigated volume mapping which use the image data directly to generate transformations throughout the coordinate system of the template and target. In some algorithms both approaches are combined via a composition of transformations. An important desirable feature of these algorithms is that they maintain the underling topology of the anatomy being mapped, restricting the class of transformations to be diffeomorphisms (one-to-one, onto and differentiable)

This talk will review some of the most recent advances in image registration algorithms and will focus on the mathematical construction of large deformation diffeomorphic transformations for landmark and volume registration. Most resent work on incorporating multiple (greater than two) imaging modalities in generating high-dimensional registration transformation will also be presented. Latest results on the accuracy of these image registration techniques for tracking organ motion during radiation treatment planning will be presented.

Educational Aims:

1) Introduce Computational Anatomy to Physics Community
2) Present the mathematical foundations of Image Registration Algorithms