William Mullally's Statement of Research Interests

I am interested in developing image-based techniques to help biomedical scientists and medical practitioners better understand and treat pathologies affecting humans and animals. My research is focused in the field of medical image analysis and its applications in clinical medicine, computational biology, bioinformatics, and biomedical engineering. I am working towards a dissertation on example-based algorithms for non-rigid medical image registration and would like to continue to conduct research on the many open challenges in image registration. Applications to disease and injury analysis intrigue me and are the underlying motivation for many of my research goals. I am both experienced and interested in addressing image segmentation problems, particularly with applications to cancer screening and radiation oncology. I am also interested in image-based statistical atlases of normal and abnormal anatomy; computational models of tissues, organs, and biological systems; lung function and physiology; brain abnormalities; and novel imaging techniques.

Registration methods are increasingly in demand by medical practitioners to accurately capture the transformations they observe in their image data. In work towards my dissertation, I propose several advances in image-to-image and model-to-image registration techniques. Existing methods are not always suitable for new clinical challenges and imaging techniques. It can be difficult to construct a single function that adequately captures concepts of similarity for multiple structures in an image, for example when aligning two images to analyze a progressive disease which causes heterogeneous changes to affected tissue. To solve this problem, I have proposed a framework for switching between similarity functions during a registration process. Initial experiments show the feasibility of this framework using a simple threshold-based function to guide the switching process. I am working on a method for learning a function to guide the switching process in this framework. This function is more generally applicable than the threshold-based function. Learning approaches for image registration are an emerging area of research with many exciting challenges I intend to continue to pursue.

Existing similarity functions for image registration do not always lead to correct solutions, so new similarity measures are needed. I am currently developing two new similarity functions that are learned from previously registered images. One of these functions uses an example-based model of the distribution of distances between pixels of different intensity values, while the second uses a learned example-based model of intensity co-occurrence over classes of segmented objects. Both of these functions draw upon a larger spatial context than typically used similarity measures such as mutual information or correlation and can be useful for multi-modal imaging problems where anatomical alignments are apparent from local image structure. Developing these and other new similarity measures will be an ongoing challenge in medical imaging as new challenges emerge from clinical and research needs.

I am interested in the application of image analysis techniques to cancer screening and cancer treatment and have worked with radiologists and radiation oncologists to develop algorithms for the segmentation of pulmonary nodules and tumors in chest computed tomography (CT) and 4DCT. I also have experience in developing methods for segmenting lymph nodes in whole body CT. While there is a large collection of work in this field, there are still many remaining problems. One such challenge I am interested in engaging is to identify and segment cancerous tissues when other pathologies are apparent in an image. Current algorithms generally do not take into account the large changes in image appearance that can be caused by some diseases and so can fail subjects suffering from multiple pathologies. New algorithms must not only address a wide range of diseases that can afflict a subject, but also handle pathologies that can affect the appearance of tissues to varying degrees.

Human anatomy and the diseases afflicting it can have a wide range of appearances in image data. It is precisely this variance in appearance that has motivated my interest in image-based statistical atlases. Such atlases have uses in diagnosis, population studies, surgical planning, biomedical modeling, and other clinical applications. I am currently developing a statistical atlas of lung fissure location for use in a study on asthma. Atlases of anatomy in the thorax are still in an early stage of development because of the high variance in image appearance of the non-rigid organs in that portion of the body. Recent successes in building multi-subject atlases of the brain along with new image analysis techniques targeting the thorax point to solutions for building more advanced atlas of the human thorax.

Statistical atlases can be particularly useful if they can be connected to computational models of tissues, organs, and biological systems. Such computational models have applications to problems that range from biomedical research on human physiology to surgical planning and predicting surgical outcomes. I am investigating a computational model used to determine which airways cause degradation in lung function of asthmatics. The model is a general instance of a bronchial airway tree that can be improved by personalizing it with the information available from image data of human subjects. There are many existing challenges on how best to use statistical atlases. I believe the best results in this area will only be achieved through the active collaboration of researchers from multiple disciplines, including biomedical engineers, computer scientists, and physicians. I intend to seek out such collaboration in much of my research, and feel it is particularly necessary for the success of biological and medical computational modeling.

In my research, I have had experience working with a wide variety of imaging modalities including CT, Magnetic Resonance Imaging (MRI), fMRI, Hyperpolarized Helium MRI, cryosection imaging, x-ray imaging, floroscopy, and optical imaging. I look forward to continuing to work with these modalities and others such as ultrasound and microscopy. My research has largely focused on images of the lung. These applications have ranged from segmenting pulmonary nodules, tumors, and other lung structures to using image registration techniques to help biomedical scientists improve their understanding of pathologies like acute respiratory distress syndrome and asthma. I am interested in continuing to work on applications targeting the lung. I am also interested in neurological imaging and pathologies affecting the brain and intend to pursue research on Chiari malformations which occur at the base of the skull.

Medical imaging is a growing field with an increasing demand for automated and semi-automated analytical tools. I have a wide variety of interests in image analysis techniques and their applications to problems that other scientists and medical professionals are working to solve. I intend to pursue an active research program both on my own and in collaboration with researchers in related disciplines and I look forward to the challenges that await me.