Prostate Registration Using the Path of the Prostatic Urethra

Prostate cancer is the leading cause of cancer death in men after skin cancer, and one in seven will be diagnosed with it in their lifetime. It is normally treated using radical prostatectomy in which the whole gland is removed causing numerous undesirable side effects. Recently, focal treatment has begun to be performed. In one form of focal therapy, needles are inserted into targets in the prostate and laser energy, cryotherapy, radioactive seeds or other method is used to destroy just the part of the prostate that contains the lesion.

The location of the cancer is usually determined using a special type of multiparametric MRI scan which is often performed several days or weeks before the surgery. It is impractical to perform the therapy with the patient in the scanner so it is necessary to determine the location of the prostate with the patient on a treatment table so that the needles can be accurately targeted. This registration problem has been previously addressed using ultrasound, however it is found that the ultrasound probe itself causes deformation and moves the prostate. It is also extremely operator dependent and can lead to error.

A proposed method of rigid registration is to use the path of the urethra within the prostate (the "prostatic urethra"). This slightly curved path is visible on the MRI scans, and may also be imaged using a few x-ray images just prior to surgery with the aid of a specially constructed Foley catheter. The technique may be extended to liver registration using catheterized vessels.

In this project the student will make use of images (provided) from a prostate phantom to determine (1) the path of the urethra from the 3D scan, and (2) the reconstructed path of the urethra from the two dimensional X-ray images containing a reference object and calculate a registration. This registration may be compared to a ground truth determined from fiducials placed on the prostate phantom prior to the scan.

Several real MRI scans will also be provided so that the theoretical accuracy of the technique may be calculated based on the path of actual urethras as it is currently unknown if the curvature is sufficient to perform an accurate registration. If time permits, the technique may be extended to liver vessel registration for the treatment of primary and metastatic liver tumours

Image Display and Planning System

Most modern commercial software systems for display and manipulation of image data do not make use of common research tools such as VTK, Matlab, 3D Slicer etc. except for prototyping. While these are ideal for research environments, commercial systems cannot usually tolerate the overhead of these platforms and the difficulty in validation. These systems also tend to be difficult to fine tune and the workflow can be cumbersome.

This project will concentrate on the construction of a basic DICOM image viewing and planning station using Open GL and C++ together with common lower level public domain packages where possible (e.g. the DICOM Toolkit, DCMTK). In this project the student will be introduced to concepts of a "commercial" software development of a basic DICOM viewing and planning station.

The software should be able to read images obtained from a CT, MRI or other scanner and display them as standard Axial/Coronal/Sagittal views as well as a 3D volume rendered view using GPU based volume rendering techniques. The images should be able to be panned, zoomed, rotated, annotated, window level adjusted etc. and various transfer functions available to manipulate the 3D view.

The software must also be able to perform a basic planning task such as setting and displaying needle trajectories, manipulation of planes representing bone cuts or resection lines etc. which are represented as graphical object overlays on the 2D and 3D images.

The student will be required to follow a stripped down version of a design and development plan that he would be expected to follow in a commercial setting, including development of a requirements document, a design document and a software validation plan.

Prostate Segmentation using Convolutional Neural Networks

Prostate segmentation is of particular interest with the development of multiparametric MRI that allows the identification of cancer sites within the prostate. By having a volumetric model of the prostate, it is possible to register the gland to ultrasound or other scans, calculate volume and perform other metrics. MRI segmentation is also an essential pre-processing task for computer-aided detection and diagnostic algorithms.

Convolutional Neural Networks (CNNs) have revolutionized the field of automated organ segmentation from diagnostic scans. In this project, the student will adapt an implementation of U-net, now considered as a baseline deep learning network for medical image segmentation. T2 image training data from the PROMISE12 (https://promise12.grand-challenge.org/home/) grand challenge will be used to train the network. The results for the prostate segmentation may be scored by the organizers of the challenge using standard metrics.

In addition to the prostate boundary, the student should investigate and potentially implement methods to segment the prostatic urethra, neurovascular bundle and other structures within the prostate.