ABSTRACT

Each year, thousands of Canadians undergo neurosurgery to areas of the brain that are critical to movement, vision, sensation, or language. Recent literature demonstrates a significantly increased survival benefit with complete resection of primary and secondary brain tumours. Image guided neurosurgery correlates preoperative diagnostic patient images with the patient on the operating room table by using a patient-to-image registration and localizing and tracking the patient and a set of surgical instruments. There are many different types of errors that can arise during image-guided interventions related to technical, physical and biological factors that largely influence the accuracy of these systems and make them unreliable as the intervention progresses or when caution is not taken to minimize their effect.

In the following dissertation, I explore the variety of different sources of errors that affect the accuracy of image-guided neurosurgical systems and establish ways in which some of them can be minimized to maximize the accuracy of these systems throughout a procedure. We begin by performing an exhaustive review of the work done investigating different sources of these errors and develop a taxonomy to better classify the sources of these errors and the state of the art techniques that aim to minimize these errors. Next, the contribution to localization, registration, and calibration errors from optical tracking systems and landmark-based registration procedures used in image-guided neurosurgery is quantified and we give suggestions to minimize their error contribution. Positioning of tools, tracking cameras and the selection of landmarks for patient-to-image registration are all important factors involved in minimizing the baseline inaccuracy contributions from image-guided neurosurgery hardware and can have major implications on system accuracy if care is not taken when using or performing them. Additionally, we explore the use of intraoperative ultrasound and augmented reality to compensate for physiological inaccuracies introduced through the phenomenon of brain shift and to maintain a high level of accuracy throughout an image-guided procedure. Finally, we show that intraoperative ultrasound is a useful tool for compensating for some of the misalignment issues when using augmented reality visualization and augmented reality complements the ultrasound by having more easily interpretable images for intraoperative visualization.
The results of the error minimizing techniques described in this dissertation suggest that with continued development, and by exercising caution while setting up and using the technology image-guided surgery can realize its potential in providing a highly accurate navigation tool to assist with complicated surgeries. With continued development and improved accuracy, these systems have the potential to be relied upon for longer durations of an operation and may make feasible more complicated, previously inoperable cases.