Joint use of image-guided surgery systems and medical robots is becoming increasingly common. Surgical navigation systems that execute predefined plans based on 3D digital models and images are now used in a wide range of non-invasive surgical applications that require both imaging and accurate surgical tool placement[1]. Applications range from Mako[2] for robot-assisted knee replacement to ROSA ONE® Brain[3], a serial arm robot for neurosurgery.

However, emerging research on these applications is difficult due to the high cost of surgical robotics hardware and the inaccessibility of medical imaging and robotics software due software licensing and the proprietary nature of the products. In addition, there are difficulties with interfacing robotics software and medical research software[1]. The robot operating system (ROS2) has a wide variety of features useful for robotics applications including computer vision, kinematics, sensing, motion planning and simulation. However, surgical planning heavily relies on medical images to localize and identify affected areas required for treatment. Furthermore, these areas must be transformed from the images into 3D coordinate space. Many of these features are available in medical image computing and image-guided therapy software. As of now, ways of integrating ROS2 and medical imaging software are limited[4]. The goal of this research project is to build an easily accessible image-guided surgery system using a collaborative robot, open-source software, and the state-of-the-art software algorithms to optimize surgical tool placement accuracy.

The image guided surgery system will be based upon the Franka Emika Panda collaborative robot[5]. Available open-source software will be used to integrate the Franka Emika robot with ROS2[6]. 3D-Slicer[7] will be used as the medical imaging software platform as it is both open-source and allows the creation of extensions to the platform in both Python and C++. The body and desired path to be cut will be modeled on 3D-Slicer which will be communicated to the robot. The open-source SlicerROS2 module[8] will be used to bridge 3D-Slicer with ROS2 allowing computer vision, imaging, kinematics, and motion planning information to be passed back and forth. In order to have tool placement accuracy comparable to modern day surgical robotics systems, camera based detection of anatomical or artificial landmarks[9] combined with state-of-the-art machine learning algorithms will be used for deformable image registration. Image registration deals with transforming two or more sets of imaging data into one coordinate system[10]. Image registration will be used to localize the position and orientation of surgical tools and the change in the tissue surface as the robot traces the desired surgical path. CNNs[11] will be used to learn features from real-time images and determine the deformable non-linear transform which models the tissue surface between the images and the coordinate system of the robot. The open-source Python library VoxelMorph will be used for deformable image registration[12]. Software will need to be written to integrate all the systems together and to create a motion planning algorithm that will trace the desired surgical path outline in 3D-Slicer. The robot manipulation platform for ROS 2, MoveIt 2, will be used to create the motion planning algorithm[13]. The accuracy of the image guided surgery system will be evaluated by comparing the position of a test cut on a model body with the desired position of the cut.

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