AbstractID: 2920 Title: Design and Calibration of a Robotic Needle Positioning System for Small Animal Imaging Applications

Purpose: A needle-positioning robot is being developed for three-dimensional micro-ultrasound guided interventions. This device will be used to perform minimally invasive injections and biopsies into small animals with high accuracy and precision.

Method and Materials: The robot has three degrees of freedom for positioning the needle in three dimensions. Two rotational joints are used to control needle orientation (roll and pitch). Another joint linearly translates the needle to perform insertion. The design features a four-bar linkage mechanism that translates the roll axis of rotation from an actuator to a remote axis that intersects the pitch and needle axes. The three intersecting axes create a remote center of motion (RCM) that acts as a fulcrum for the three-dimensional orientation of the needle. The RCM corresponds to the insertion point of the needle into the animal. In order for the robot to achieve high accuracy, it must be calibrated to ensure that the three axes intersect at a single point, and the needle tip must be positioned at the RCM. The calibration was performed using a macro lens CCD camera to find the center of rotation about the pitch and roll axes separately. The position of the needle was adjusted until it was aligned with the RCM.

Results: The range of motion is ±30º, ±45º, and 20 mm for the pitch, roll, and needle axes, respectively. Initial calibration results indicate that the distance from the needle to the pitch and roll axes are 24 ± 30 μm (mean ± standard deviation of five trials) and 18 ± 15 μm, respectively. The pitch and roll axes are separated by 11 ± 3 μm.

Conclusion: The expected maximum needle positioning error computed from the calibration results is 32 μm when the needle tip is moved to the boundary of the workspace.