Robotic System for Central Line Placement
Design Document

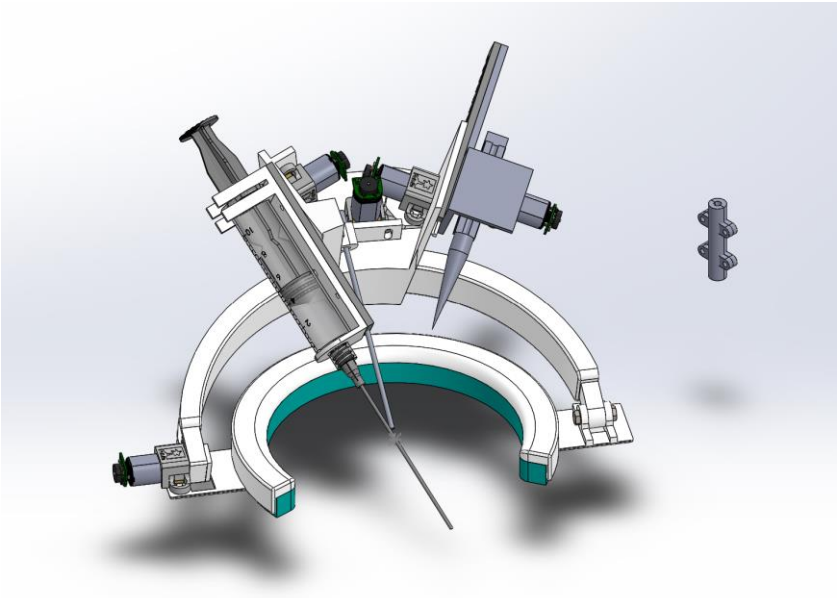

Figure 1: Isometric view of the overall design

The robotic system consists of five parts: the base, the arc, and the carriage, the needle insertion actuator, and the guidewire & catheter advancement actuator, as shown in Figure 1. It has 2 rotational degrees of freedom (DoF) and 2 translational DoF. The angular workspace of insertion is 13 degrees to 50 degrees relative to the skin, and the depth workspace is 19.8 mm to 67.4 mm. The mechanical remote center of motion (RCM) is 8.5 mm above the skin.

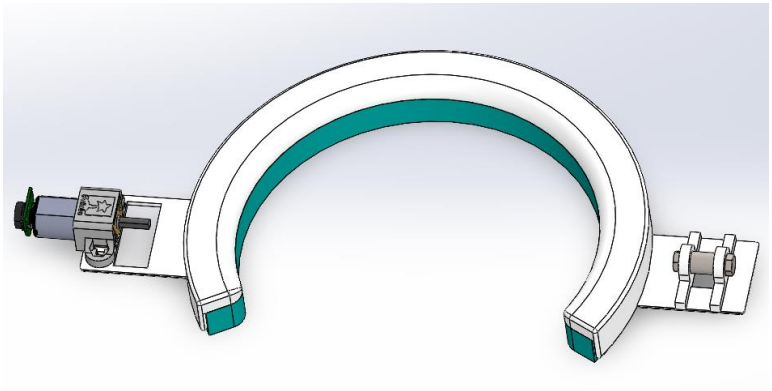

Figure 2: Details of the base

The base includes a GelPort and a rigid base, as shown in Figure 2.

1. GelPort, a sticky soft material generally used in laparoscopic surgery, holds the robot on the patient.
2. The rigid base sticks on the GelPort, which connects the GelPort and supports the arc.

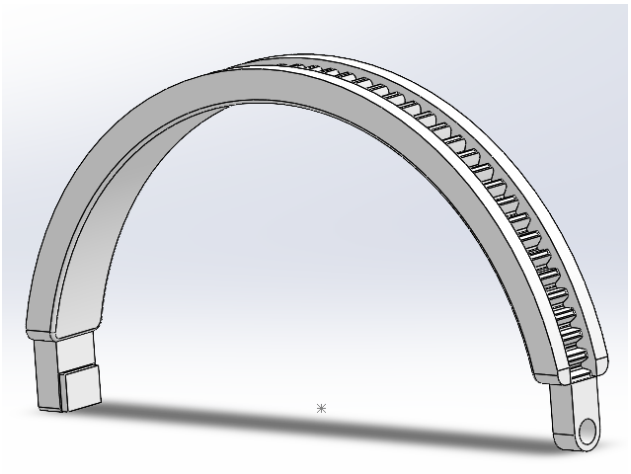

Figure 3: Details of the arc

The arc is connected to the rigid base and is driven by a step motor attached to the rigid base to provide one rotational DoF along the y-axis, as shown in Figure 3. The teeth on the arc are matched with the gear on the carriage, providing restrictions on the motion of the carriage.

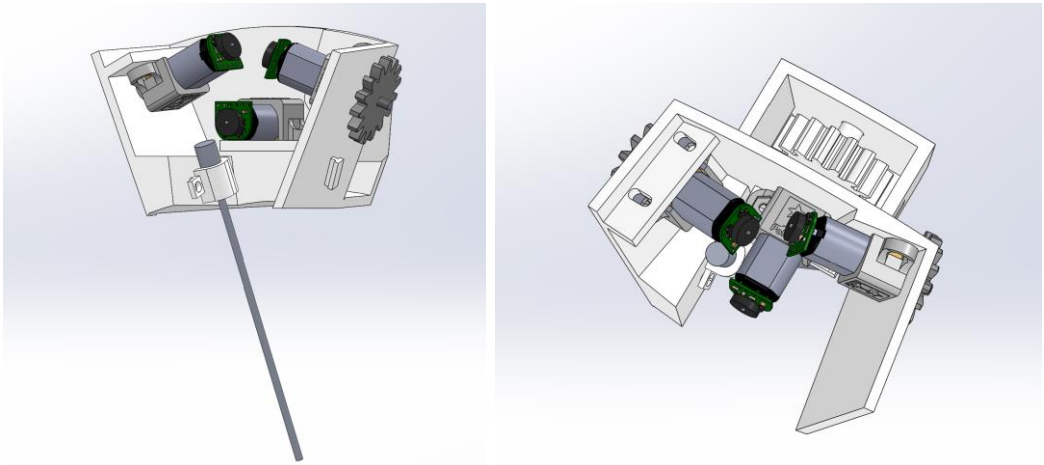

Figure 4: Details of the carriage

The carriage uses a circular rack and pinion gear mechanism to slide over the arc, as shown in Figure 4. There is a small gear on the carriage driven by a step motor on the back to provide one rotational DoF along the x-axis. There is a laser pointer bucket at the bottom of the carriage, holding the laser pointer to indicate the RCM when rotating. There is a motor on each side of the carriage, driving the needle insertion actuator and the guidewire & catheter advancement actuator separately to provide two translational DoF. As both actuators use a rack and pinion gear mechanism to move along the carriage, there are pinions attached to the shaft of the motors and sliders matched with the racks on the actuators to provide restrictions on the motion.

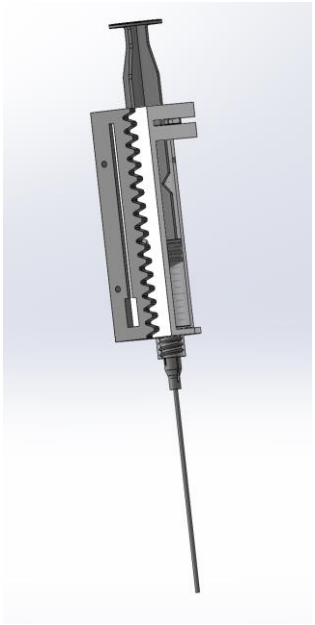

Figure 5: Details of the needle insertion actuator

The needle insertion actuator is a holder of the needle syringe, as shown in Figure 5. There is a rack on the back of the holder, which is coordinated with the pinion on the carriage. There is a guide rail on the rack, which is coordinated with the slider on the carriage.

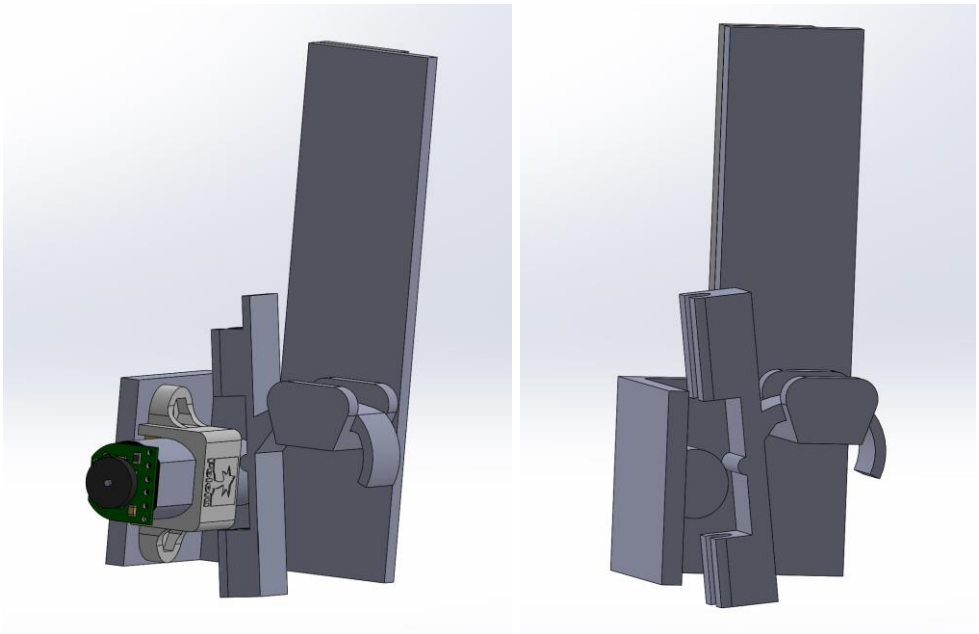

Figure 6: Details of the guidewire & catheter advancement actuator

The guidewire & catheter advancement actuator is as shown in Figure 6. Similar to the structure of the needle insertion actuator, there is a rack on the back of the actuator, which is coordinated with the pinion on the carriage. There is a guide rail on the rack, which is coordinated with the slider on the carriage. A detachable guidewire & catheter feeder is held on the actuator, allowing the guidewire and catheter to go through and restricting the direction of their movements. The feeder is coordinated with a roller driven by a step motor to advance the guidewire and catheter.