An Aiming Device for Steerable Needles

Margaret Rox‡, Maxwell Emerson‡, Tayfun Efe Ertop‡, Mengyu Fu†, Inbar Fried†, Janine Hoelscher‡, Alan Kuntz§, Josephine Granna§, Jason Mitchell§, Michael Lester†, Fabien Maldonado†, Erin Gillaspie‡, Jason Akulian‡, Ron Alterovitz‡, Robert J. Webster III‡
* Vanderbilt University, Nashville, TN 37203, USA
‡ University of North Carolina at Chapel Hill, NC 27599, USA
§ University of Utah, Salt Lake City, UT 84112, USA
†Vanderbilt University Medical Center, Nashville, TN 37212, USA

Abstract—Steerable needles are capable of curved paths through soft tissues, which is useful for steering around obstacles and compensating for deviations from the intended needle path. However, the ability to reach a desired target still depends on setting the initial needle launch pose such that the desired target is within the needle’s workspace. Thus, it is desirable to have a means of adjusting the needle’s launch orientation locally at the tissue entry point. In this paper we present a new aiming device for steerable needles that locally adjusts needle launch orientation. It consists of a tendon-actuated, notched tube design, which enables adjustment of the needle’s initial orientation.

I. INTRODUCTION

Steerable needles have been the subject of substantial research in recent years, to enable curved trajectories that steer around obstacles and to compensate for unmodeled effects that knock needles off-course during insertion [1]. Steerable needles exhibit a trumpet-shaped workspace defined by their maximum curvature. The ability to hit a desired target depends on that target being within this workspace at the start of needle insertion. Anatomical constraints can sometimes make this challenging, motivating the development of a new mechanism that can locally adjust needle orientation at the tissue entry point. In this paper we provide such a mechanism.

Notched tube flexure mechanisms have been introduced in the literature as wrists for needle-sized manipulators [2]. An improved notch shape was introduced in [3] to a new application, i.e., aiming a steerable needle. The aiming device, shown in Figure 1, is made from a beveled nitinol tube (OD 1.78 mm) with notches that are laser cut to a depth of 70% of the total diameter of the tube. It is actuated using a tendon pulled from its proximal end. As the tendon is displaced, the aiming device bends. This provides a means of locally adjusting the launch angle of the needle. Combined with axial rotation, two degrees of freedom can be controlled.

Fig. 1: A photo of the aiming device. The notch profile enables it to bend, aiming the steerable needle toward the target.

Fig. 2: The aiming device in Knox Gel (a) unactuated, (b) actuated, and (c) actuated with a steerable needle deployed through it.

II. PHANTOM TISSUE DEMONSTRATION

We tested the aiming device in a 10% by weight Knox Gelatin phantom, using the robotic system described in [4]. The aiming device was inserted into the phantom with the steerable needle inside it, as shown in Figure 2(a). The tendon was then pulled to bend the aiming device, as shown in Figure 2(b), adjusting the needle’s launch angle. Note that when the tendon is released, the stiffness of the wrist itself restores the aiming device to its original pose. We then deployed a steerable needle through the actuated aiming device, which can be seen in Figure 2(c).

III. CONCLUSION

Notched tube designs have previously been used as surgical robot manipulators, but this is the first time they have been used in a steerable needle system. They provide a means of locally adjusting needle launch angle, which is desirable to ensure that the intended target is within the needle’s workspace.

REFERENCES