Image Guidance of Active Cannulas

**Introduction: Active Cannulas**

- Active cannulas are miniature, highly compliant, dexterous robots ideal for navigating tortuous anatomy
- Made from concentric pre-curved flexible (Nitinol) tubes
- Actuated from the base via tube rotation & insertion
- Small diameter design; inherent miniaturization
- Tunable stiffness through tube selection; compliance enhances safety
- Mechanically simple; actuated robotically or manually

**The Problem**

- Active cannula compliance renders the final pose difficult to predict from forward kinematics alone.

**The Solution: Image Guidance**

**Kinematics of Active Cannula**

- Cannula shape can be expressed in terms of piecewise planar arcs. Tip pose is the result of all the arcs:
  \[ g = g_0 g_1 \cdots g_m, \quad g_j = e^{\Delta \phi_j} e^{(e_3 + e_2 e_3) \varepsilon_j}, \quad j = 1, 2, \ldots, m, \]
- Cannula shape is determined through minimization of stored elastic energy.
- Jacobian relates velocities of the cannula tip (or any other point on the cannula) to joint velocities:
  \[ V_{st} = (gg^{-1})^\top = J_{st} \dot{q} \]

**Impact and Future Work**

**Impact**

- Image-guidance will facilitate tele-operated and fully automatic control strategies.

**Future Work**

- Validate for many tubes; many degrees of freedom.
- Combine the open-space dexterity of active cannula with the in-tissue dexterity of steerable needles.
- Develop algorithms for medical imaging modalities.

**PEOPLE INVOLVED**

- Graduate students: John Swensen (JHU)
- Undergraduates: Joe Romano (JHU; now @ Penn)
- Engineering Faculty: Noah Cowan (JHU) and Robert Webster (Vanderbilt)

**SUPPORTED BY:**

- NIH Grant R01-EB006435
- NSF Grant CBET-0651803
- CISST ERC (NSF Grant EEC-9731748)

**PUBLICATIONS**