Using Continuum Robots to Enable Transoral Access to the Peripheral Lung for Minimally Invasive Biopsy

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Motivation
- Lung cancer kills more people than any other cancer. (~160,000 in 2014, USA)
- Biopsy is the standard for diagnosis.
  - CT-guided percutaneous biopsy
  - Bronchoscopic biopsy

Problem
- **Risks**: Percutaneous biopsy breaks the pleura—risk of pneumothorax.
- **Limits**: Bronchoscopic methods only reach regions adjacent to bronchii.
- Early-detected nodules are small—difficult to biopsy with either method.

Methods
- We augment a **bronchoscope** with a **concentric-tube** robot and a flexure-tipped **steerable needle**:
- Enables access to the peripheral lung for biopsy without puncturing the pleura.
- Proposed **workflow**:
  1. Insert the bronchoscope
  2. Deploy concentric-tube robot
  3. Insert the steerable needle

Experimental Results
- **Experimental setup**:
  - Tissue phantom (agar gelatin)
  - Bronchial phantom (clear PVC)
  - Porcine bronchial wall sample
- **Workflow experiments**:
- **Open-loop trials in ex vivo porcine lung**:
- **Closed-loop targeting in tissue phantom using magnetic tracking system**:

Robot Prototype
- **Concentric-tube Robot**
  - Concentric, pre-curved, elastic tubes move like tentacles when translated and rotated relative to each other.
- **Steerable Needle**
  - An asymmetric needle-tip causes the needle to turn when inserted through parenchyma.

Experimental setup:
- Bronchoscope
- Tissue phantom (agar gelatin)
- Porcine bronchial wall sample
- Experimental workflow:
  1. Manually insert the bronchoscope
  2. Deploy concentric tubes
  3. Insert steerable needle

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