Simulation and Automatic Navigation of an Intravascular Interventional System

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Outline

- Introduction
- Literature Review
- Ongoing & Future work
Introduction

Catheterization
-Passage of a catheter into a body channel or cavity.

Cardiac catheterization


Image source: Stanford Hospital & Clinics
Current Techniques

Robotic-assisted Systems

• Magellan Robotic System
• CorPath 200 System

Magnetic Navigation Systems

• Niobe II System

Hansen Medical: Magellan Robotic System

Stereotaxis: Niobe II System
Motivation

Risk of vascular access procedures

• Damage to blood vessels due to the complexity of the blood vessel structure or improper operation.

• Slipping into the wrong blood vessel.
Goals

• Design an automatic navigation system of catheterization, especially for branched arteries, to make the vascular surgery easier and more efficient.

Navigation System

Control

Navigation

Simulation
Control System

Reference Input (Desired) → Controller → Catheter

Error → Control Signal
- Forwarding
- Backwarding
- Twisting

Disturbance → Viscous resistance, etc.

Actual Output → Sensor / Transducer → Position of the Catheter tip

Feedback
Navigation

• Medial axis and local radius information

• Catheter Positioning
  ▪ Fluoroscopy (conventional method)
  ▪ ultrasonic transducers

Image source: Hansen Medical
Simulation

• Catheter Modeling
  – Simulate the non-linear deformation of wire-like structures
  – Define a large number of constraints to confine the catheter inside the vascular network

• Vessel Modeling & Simulation
  – Catheter in vessels
  – Effect of arterial flow
Related Work

• Geometric Based Catheter Modeling

-- Simulated Modeling and Image Processing for Intra-Cardiac Interventional Diagnosis and Therapy, Patricia Chiang Wei Yin
Related Work

- FEM Model: Incremental FEM method (multi-body system)

-- New approach to catheter navigation for interventional radiology simulation, Harvard Medical School etc.
Related Work

• Kinematic Modeling

Ongoing Work

• Test and simulate the physical properties of the catheter based on geometrical method
  – Slipping behavior
  – Relationship between the bending curvatures and twisted angles
  – The properties of formed contact points between the catheter and the vascular wall
Ongoing Work

- Navigation strategy of the catheter at arterial bifurcations
  - Test using the bifurcation phantom
  - Integrate with the automatic operation system
Future Work

• Experiment on catheters with different tip shapes
• Compare results with real tissues
• Take the motion of vessels and blood flows into consideration