Development and Control of Assistive Surgical Robots

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Our Vision: Robotic Assistants

- Surgeon conducts the operation
- Robot only assists with a simple task

Da Vinci Surgical System VS Robotic Assistant
Outline

Endoscope Holder for Sinus Surgery

Uterus Positioner for Hysterectomy

Automatic Soft Object Manipulation
Endoscopic Sinus Surgery

- Common procedure (usually) conducted to enlarge the sinus channels
Traditional Surgery

- The surgeon manipulates endoscope and instrument
Two Hand Operation

- Requires help from assistant surgeons
Proposed Robotic Assistant

- Eight motorised DOF

P Li, HM Yip, D Navarro-Alarcon, YH Liu, et al., ICIA (2011)
First Prototype

- RCM-based design
User Interface

- Control **one joint** at the time
- Motion commanded with a **foot pedal**
- Axis selected with a **foot switch**
Experiments

- Ex-vivo test

CUHK, June 2012
Second Prototype

- Four motorised DOF
IMU-based Interface

- Foot gestures to select and command motion

WY Lin, D Navarro-Alarcon et al., IROS (2015)
Experiments

- Two-hand operations

Ex-vivo test. Dissection laboratory, School of Biomedical Sciences, CUHK
Outline

Endoscope Holder for Sinus Surgery

Uterus Positioner for Hysterectomy

Automatic Soft Object Manipulation
Laparoscopic Hysterectomy

- Remove the patient’s uterus
Traditional Approach

- Laparoscopic ports for instruments and camera
Uterine Manipulation

- Long and tedious task
Task Workspace

- Two rotations, one insertion
Proposed Robotic Assistant

- Four motorised DOF, passive flexible joints

HM Yip, P Li, D Navarro-Alarcon et al., Jrobio (2015)
Control System

- Compact (low driving power, up to 1A/axis)

HM Yip, ZR Wang, D Navarro-Alarcon et al., TMECH (2015)
User Interface

- Speed commands for yaw/pitch directions
Experiments

Ex-vivo cadaver test at the PWH 2014
Outline

Endoscope Holder for Sinus Surgery

Uterus Positioner for Hysterectomy

Automatic Soft Object Manipulation
Manipulation of Rigid Objects

Extensively studied for more than five decades

UNIMATE, circa 1961

Tokyo 2013
Rigid Bodies vs Soft Bodies

- **Rigid**: Fixed geometry
- **Soft**: Shape is modified by physical interactions

Yoshikawa (2010)
Great Economic Value

Automate:
- Food industry
- Home/personal robotics

Tokumoto et al. (2001, 2002)

Cusumano et al. (2011)
Great Economic Value

- Handling of linear objects
- Robotic surgery

Saha et al. (2007)

Torabi et al. (2009)
The Problem We Address

- **Uncalibrated** image-guided manipulation of soft objects with *unknown* model
Our Approach

Simultaneous control of:

- **3D position** of a feature point
- **Shape term** (compression, angles, curvature)
Experiments

- Set-up
Conclusions

- We developed **robotic assistants** for sinus surgery and hysterectomy
  - Prototypes

- We developed methods to manipulate **soft objects**
  - Model-free

- **Future** work: **Clinical** trial
Collaborators

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