LABORATORY FOR Computational Sensing + Robotics THE JOHNS HOPKINS UNIVERSITY

JOHNS HOPKINS MEDICINE

Paper Presentation: Robotic Assistance to Flexible Endoscopy by Physiological Motion Tracking

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Group 13: Robo-ELF

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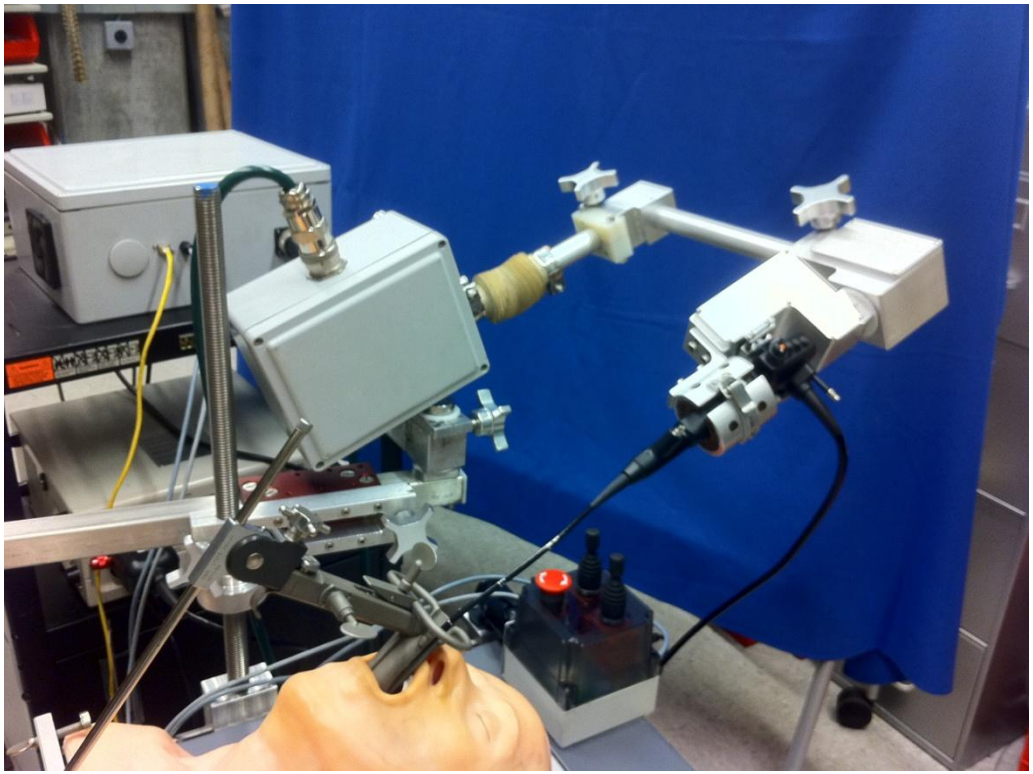
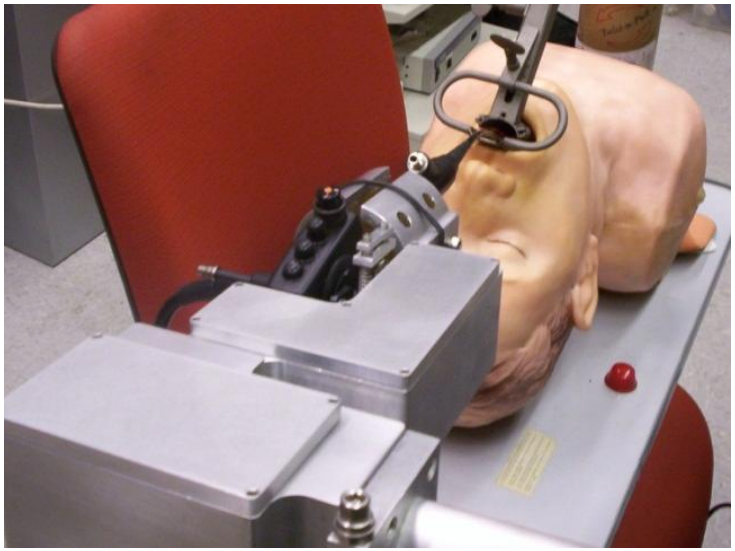
Project Background

- Robotic EndoLaryngeal Flexible Scope (Robo-ELF) system for endoscope manipulation





Paper Selection and Relevance

- **"Robotic Assistance to Flexible Endoscopy by Physiological-Motion Tracking"**

  Laurent Ott, Florent Nageotte, Member, IEEE, Philippe Zanne, and Michel de Mathelin, Senior Member, IEEE

  IEEE Transactions on Robotics, April 2011

- Robotically control an endoscope
  - Use visual servoing to compensate for breathing movement and motor backlash
  - Similar goals and methods to our project

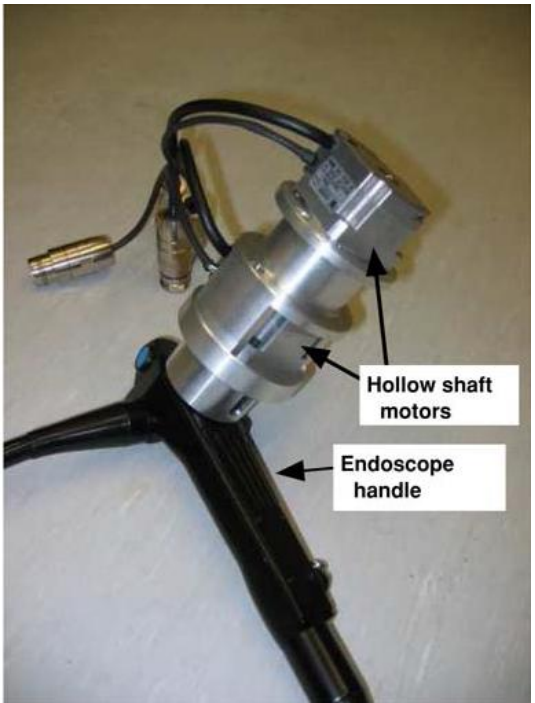
Goals and Motivation

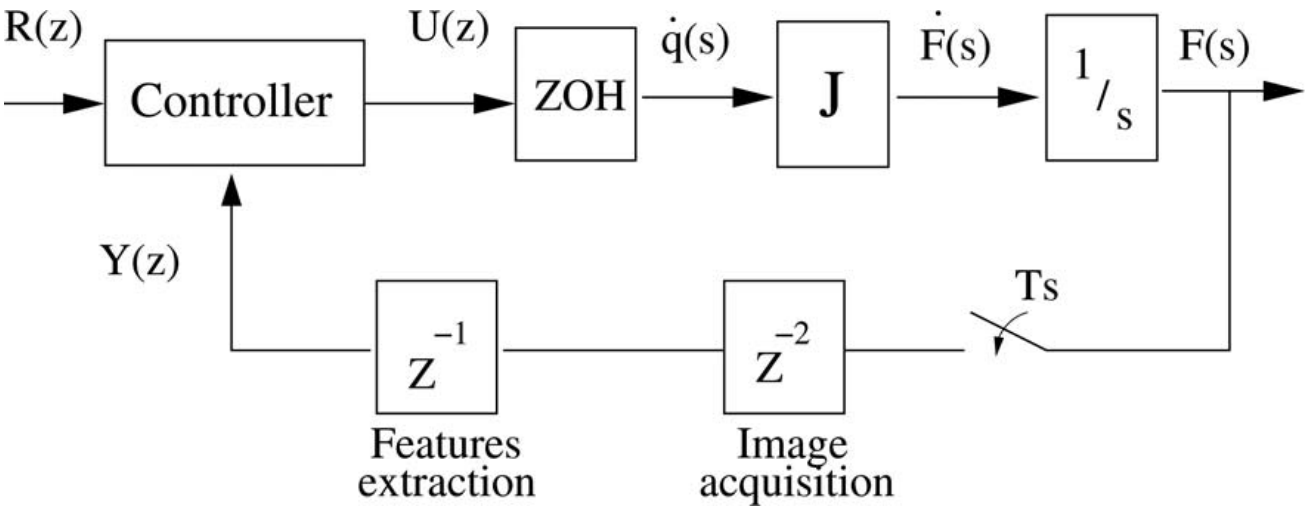
- Endoscope is very difficult to control during surgery, especially with an unstable image
- Use robotic controls to stabilize endoscope image during Minimally Invasive Surgery
- Compensate for periodic breathing motion
- Compensate for motor backlash
- Develop forward kinematics for the flexible endoscope

Ott, Nageotte, Zanne, de Mathelin. 2011

System Design

- Replaced control knobs with motors
- Manual control possible using joystick
- Computer control using visual servoing

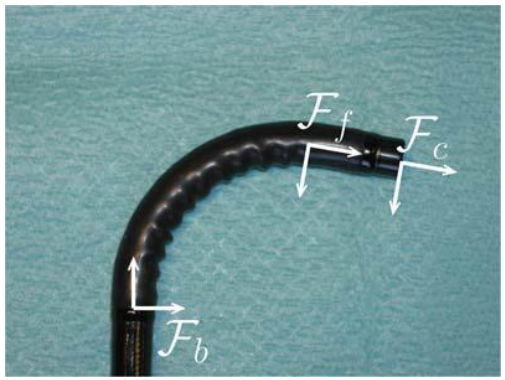




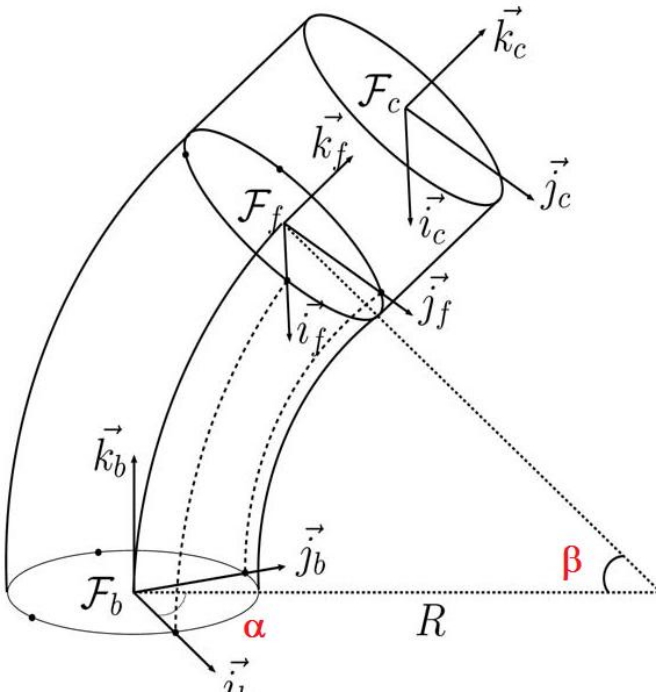
Ott, Nageotte, Zanne, de Mathelin. 2011

Kinematics of the Endoscope

- Find transformation between Fb and Fc
- Calculate image velocity in terms of α and β
- Find α and β in terms of motor position counts



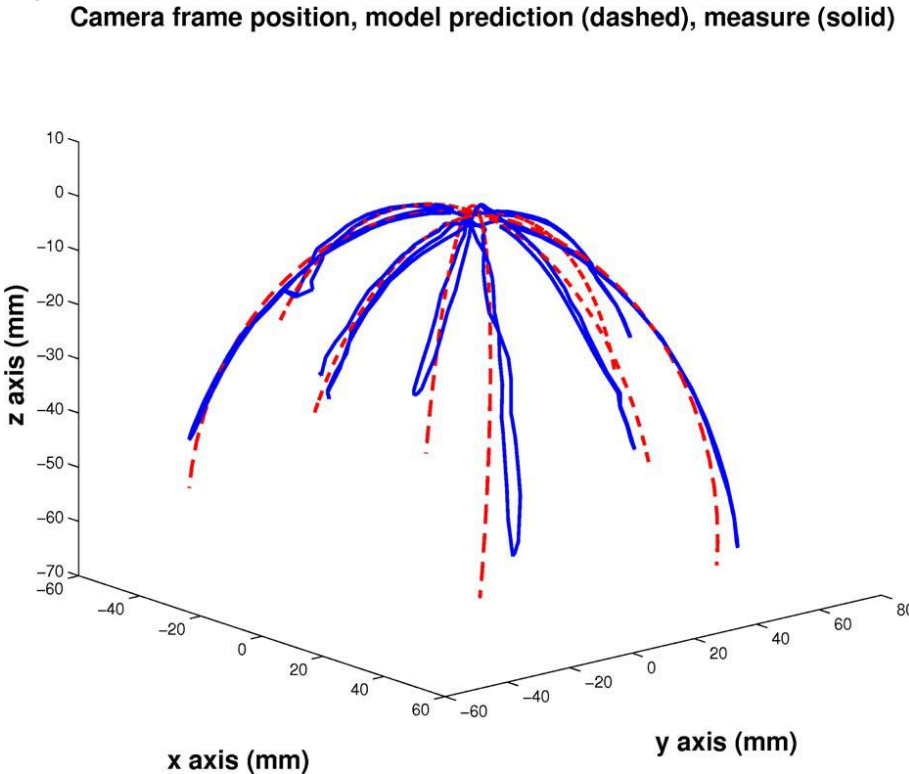
Ott, Nageotte, Zanne, de Mathelin. 2011



Kinematic Model Validation

- Rotate scope tip through workspace and compare positions calculated by the model predictions and by measurements

- Translation error: **7.36mm**
- Rotation error: **11.93°**
- Workspace error:
  2.78mm, 8.98°

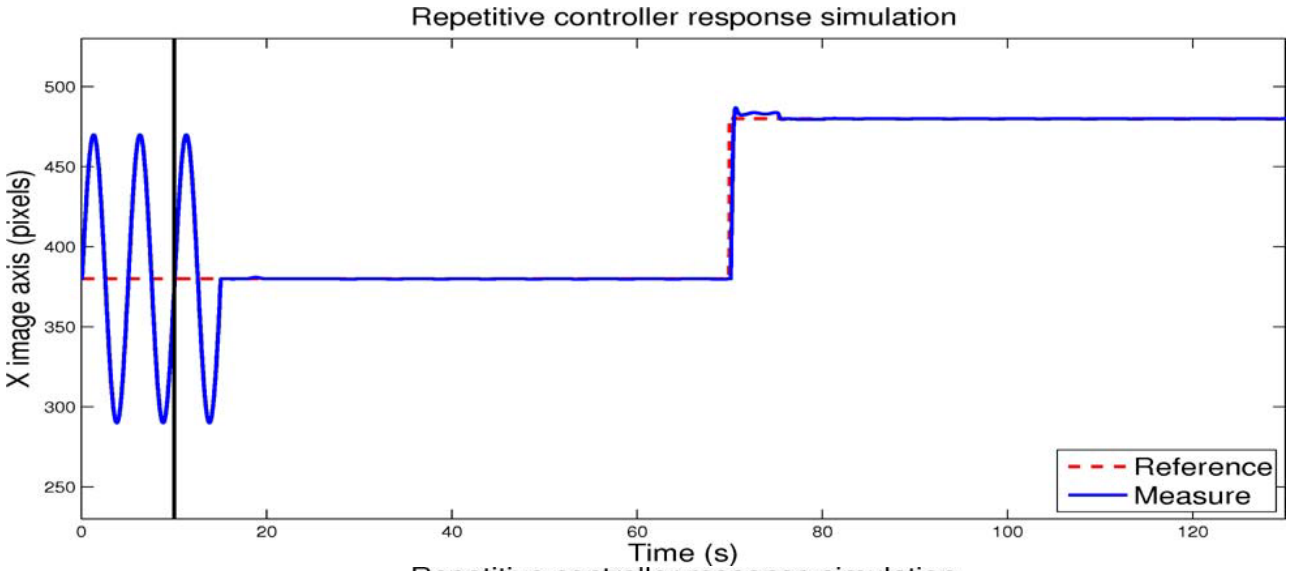


Periodic Motion Cancellation

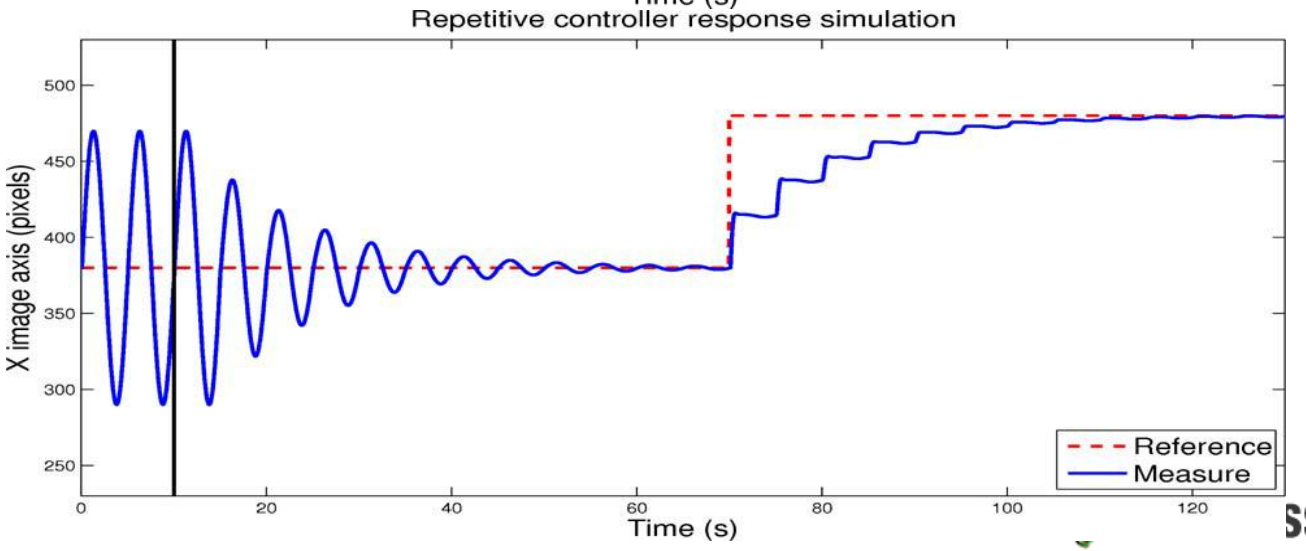
- User chooses target in image to stabilize on
- Motion is too fast to compensate for using only standard PID control
- Repetitive control with feedforward implemented to cancel motion

Results of Motion Cancellation(Simulation)

Without depth error



With depth error

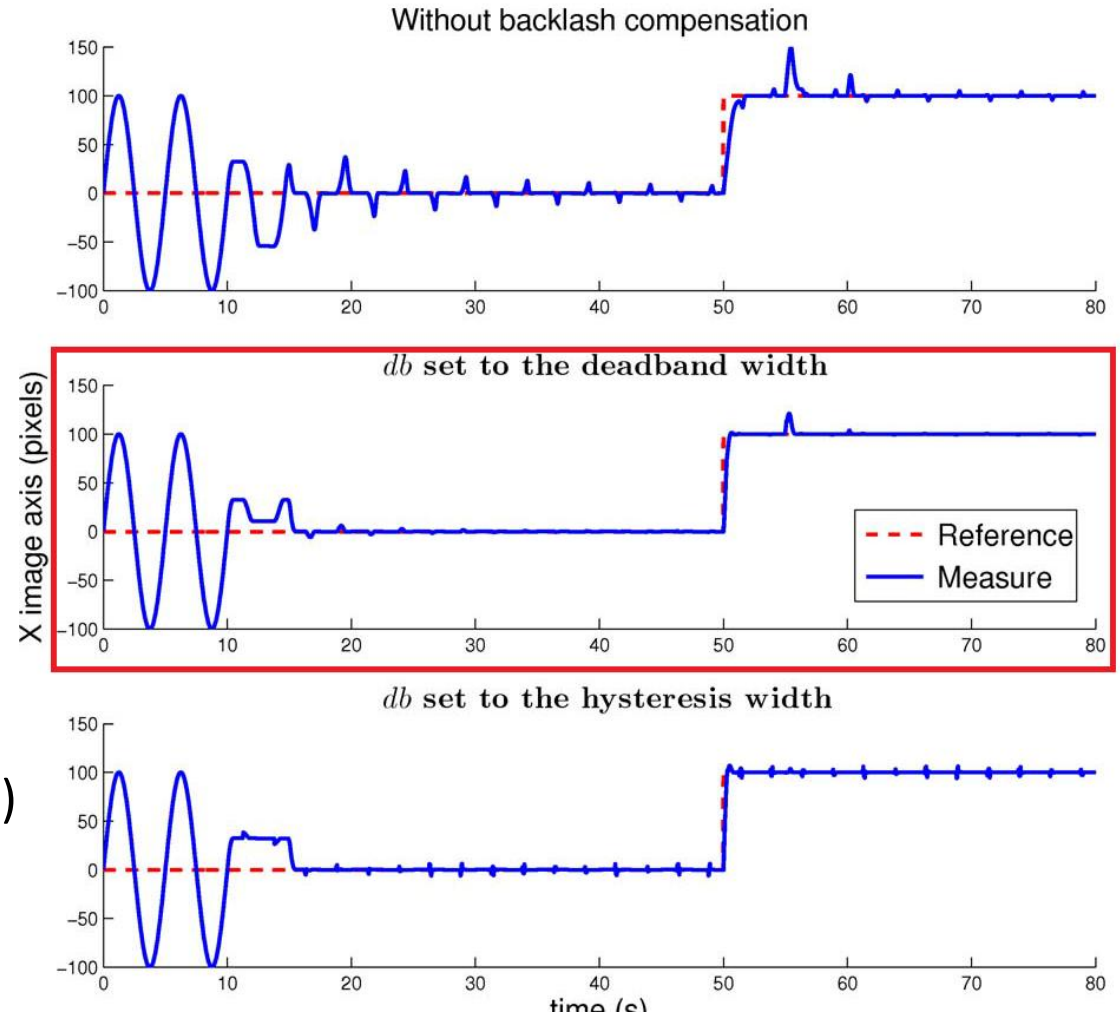


Backlash Compensation

- Motor backlash is delay between applied control and actual movement, a result of gaps or slackness in gearing mechanisms
- Deadband in motion when changing direction
- Can be measured and eliminated
- Strategy is to add an extra movement, ***db***, when direction of motion is reversed

Backlash Compensation Results

- Deadband width provides best results
- Hysteresis(non-linear region) width overcompensates



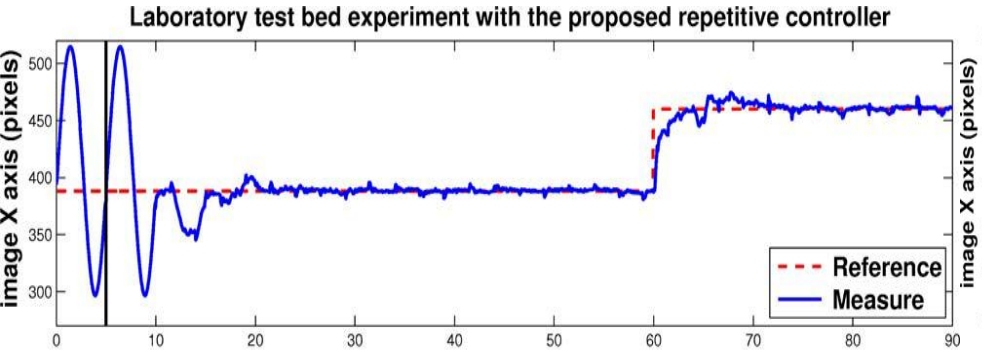
Experiments and Results

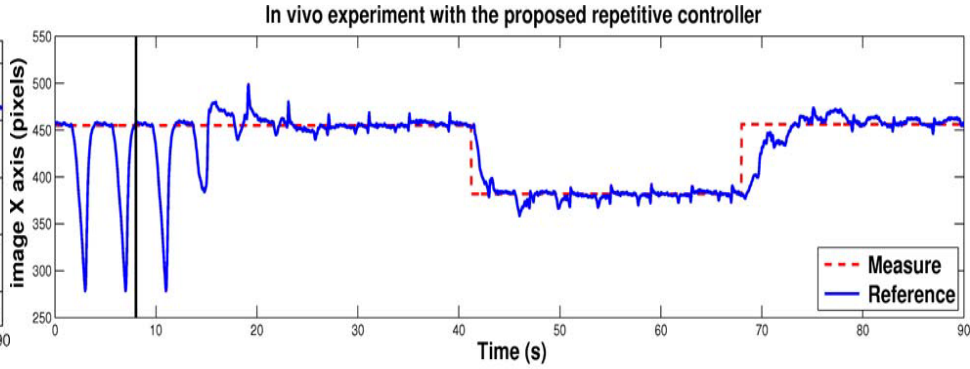
- Phantom experiment in lab
  - 80-90% reduction in image motion
  - 25mm motion reduced to 2mm

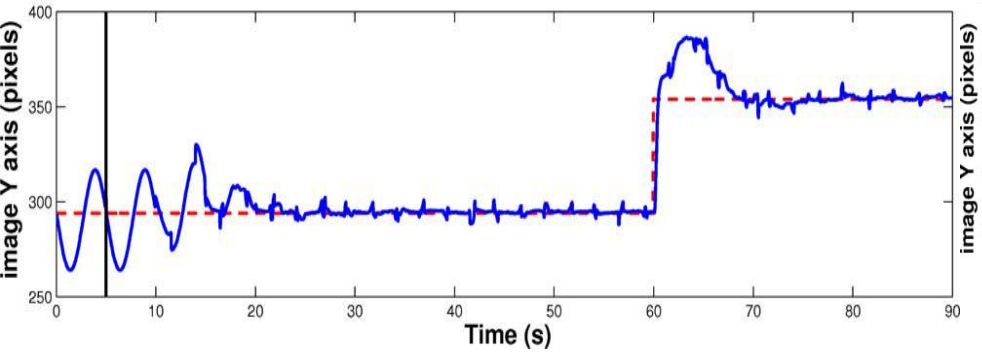
- *In vivo* experiment on anesthetized pig
  - ~80% reduction in image motion
  - 12.7mm reduced to 1.7mm

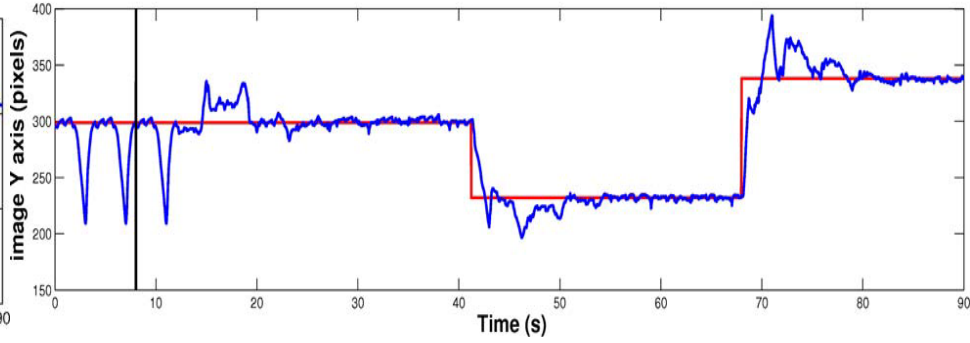
Experimental Results

- Phantom Results
- In Vivo Results









Conclusions

- It is possible to perform breathing compensation using a flexible endoscope and only its embedded vision system.
- System could be extended to compensate for motion parallel to the camera axis, requires stereo vision

Paper Analysis

Good Things:

- Thorough description of mathematical models and analysis.
- In vivo experiment showed excellent results

Bad Things:

- Didn't address potential problems with feature recognition and tracking
- Model validation lacks detail
  - How many trials in avg?
  - What is the setup?
- Few trials shown in experiments

Application to Our Project

- Our possible future work includes breathing and backlash compensation.
  - Adapt Robo-ELF to bronchoscope
- Example of a working system using visual servoing to control a flexible endoscope
  - Same thing we are trying to do!

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Thank You

Questions?

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