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Soft robotics for minimally invasive surgery

Prof Kaspar Althoefer

Faculty of Science & Engineering

ARQ - Centre for Advanced Robotics @ Queen Mary

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Outline

- State of the Art in Robot-Assisted Minimally Invasive Surgery
- Advancing Soft Robotics for Surgical Applications
- Stiffness Controllability
- Challenges

EUROPEAN COMMISSION
European Research Area

SEVENTH FRAMEWORK PROGRAMME

STIFF FLOP

State of the Art in Robot-Assisted Minimally invasive Surgery

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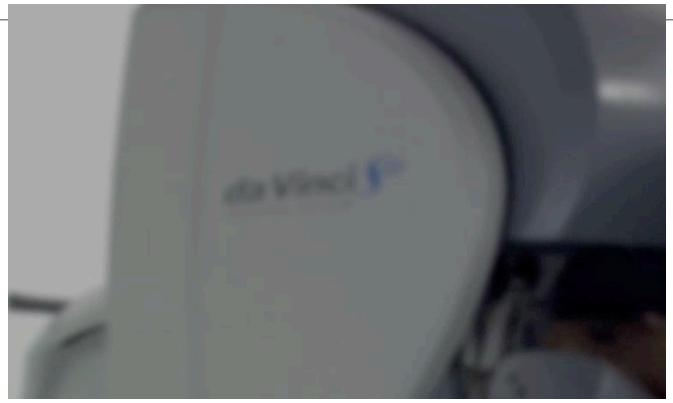
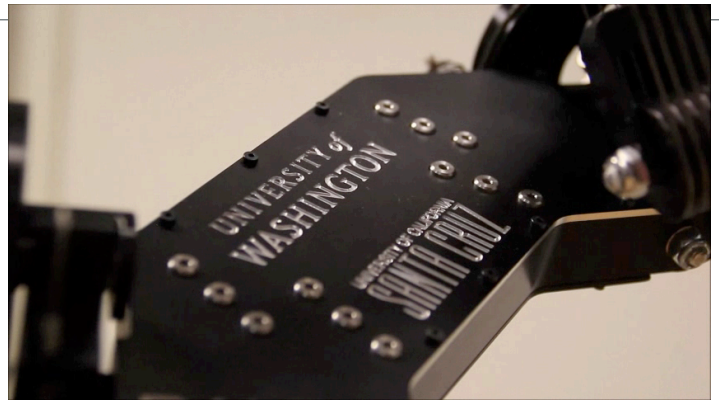
Surgical Robotics



Da Vinci



Raven

Miro

Robin Heart

Current Flexible Robots for MIS

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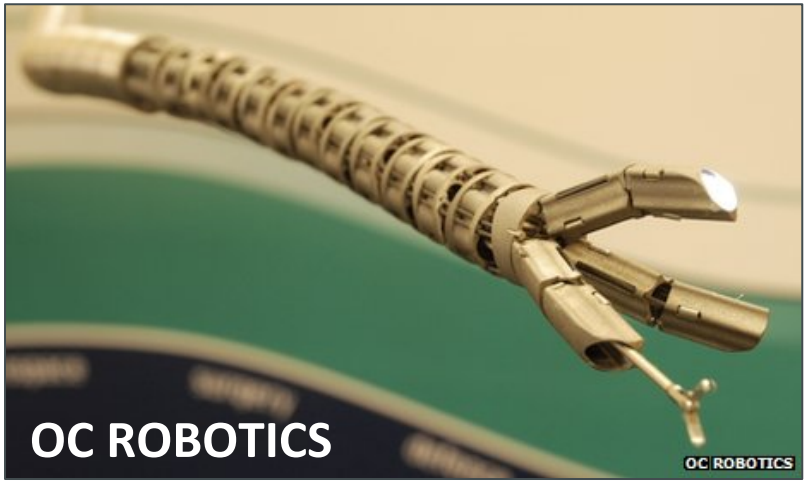
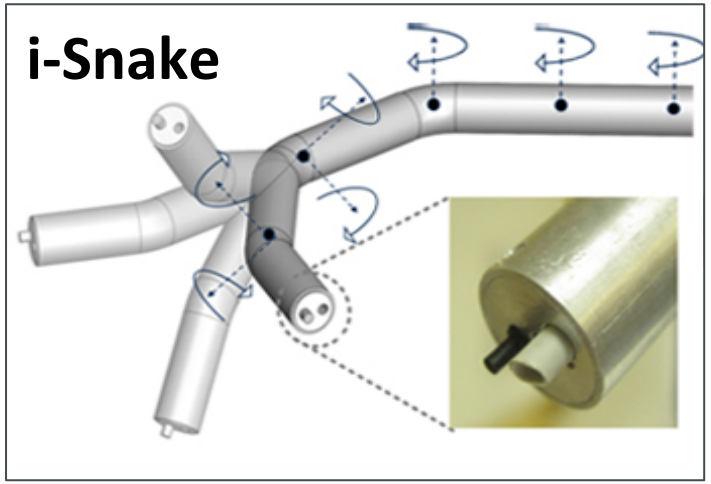
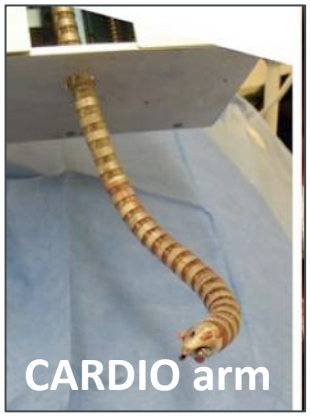
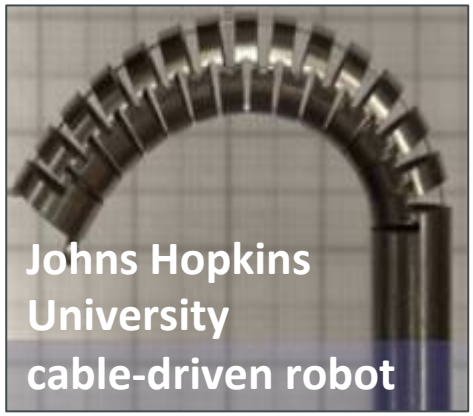
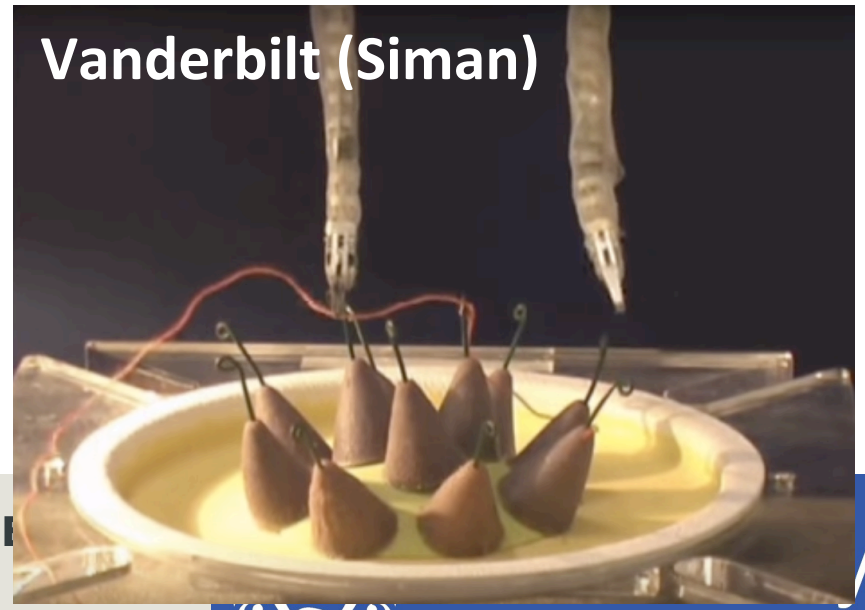
SEVENTH FRAMEWORK PROGRAMME







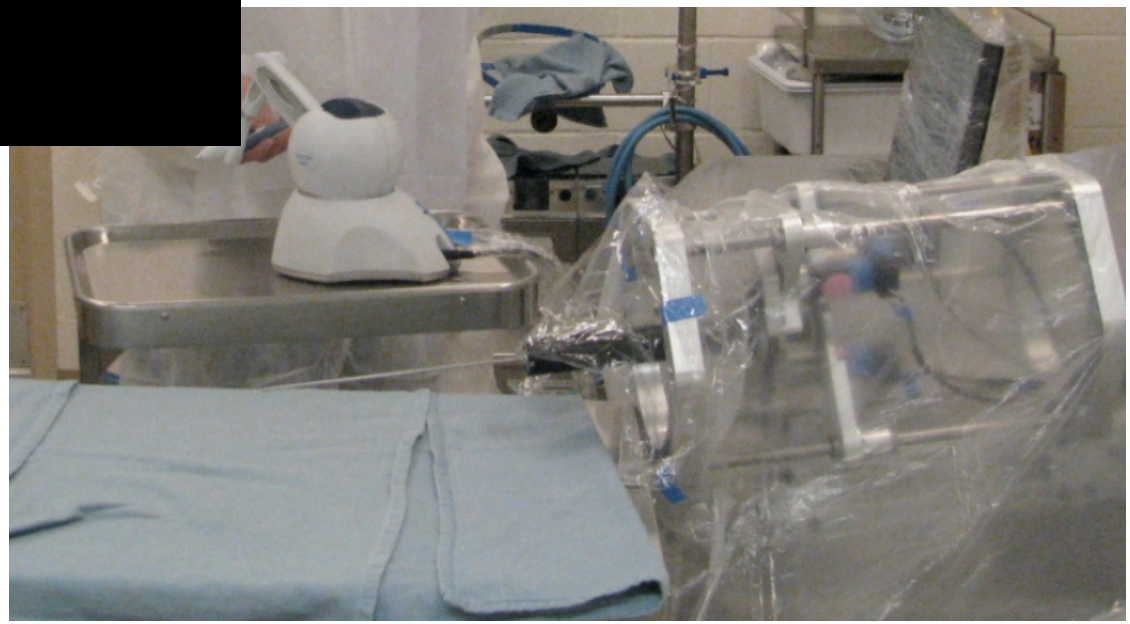




Teleoperation of an Active Cannula
MED Lab, Vanderbilt University

Concentric Tube Robot

Vanderbilt (Webster)



Concentric Tube Robot

Boston (Dupont)

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SEVENTH FRAMEWORK
PROGRAMME

STIFF flop

Advancing Soft Robotics for Surgical Applications

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SEVENTH FRAMEWORK PROGRAMME

STIFF flop

STIFFness controllable Flexible and Learnable manipulator for surgical OPerations

January 2012 to December 2015
Coordinator:
King's College London
Department of Informatics
Centre for Robotics Research (CoRe)

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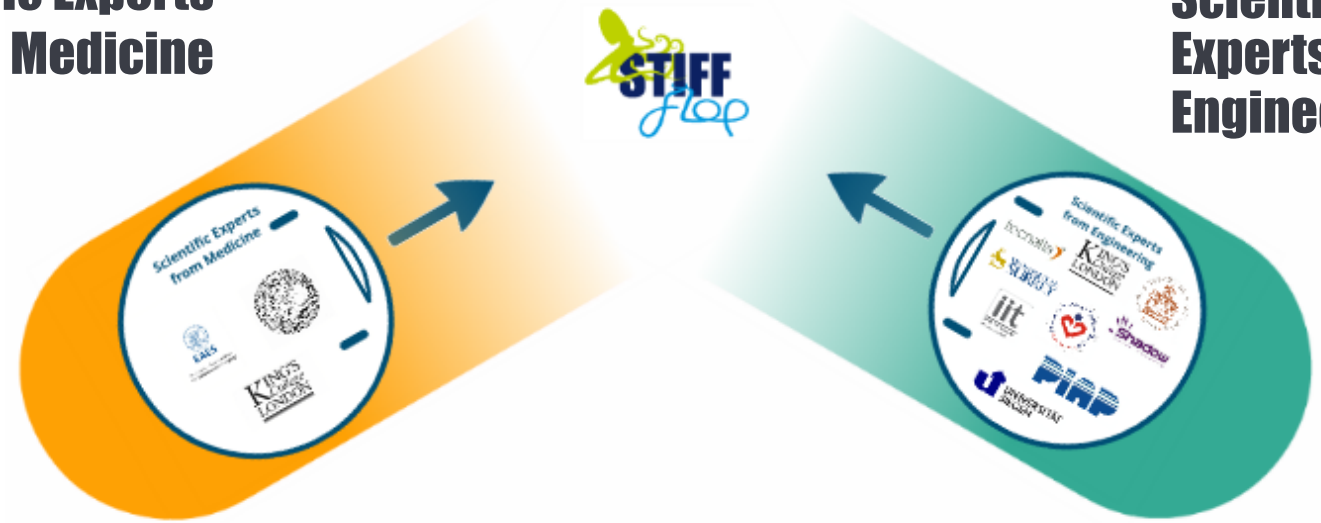
SEVENTH FRAMEWORK PROGRAMME

STIFF-FLOP

Scientific Experts from Biology

Scientific Experts from Medicine

Scientific Experts from Engineering



Flexible robots of controllable stiffness for minimally invasive surgery: the STIFF-FLOP project

ICRA 2017 workshop C4 Surgical Robots: Compliant, Continuum, Cognitive, and Collaborative

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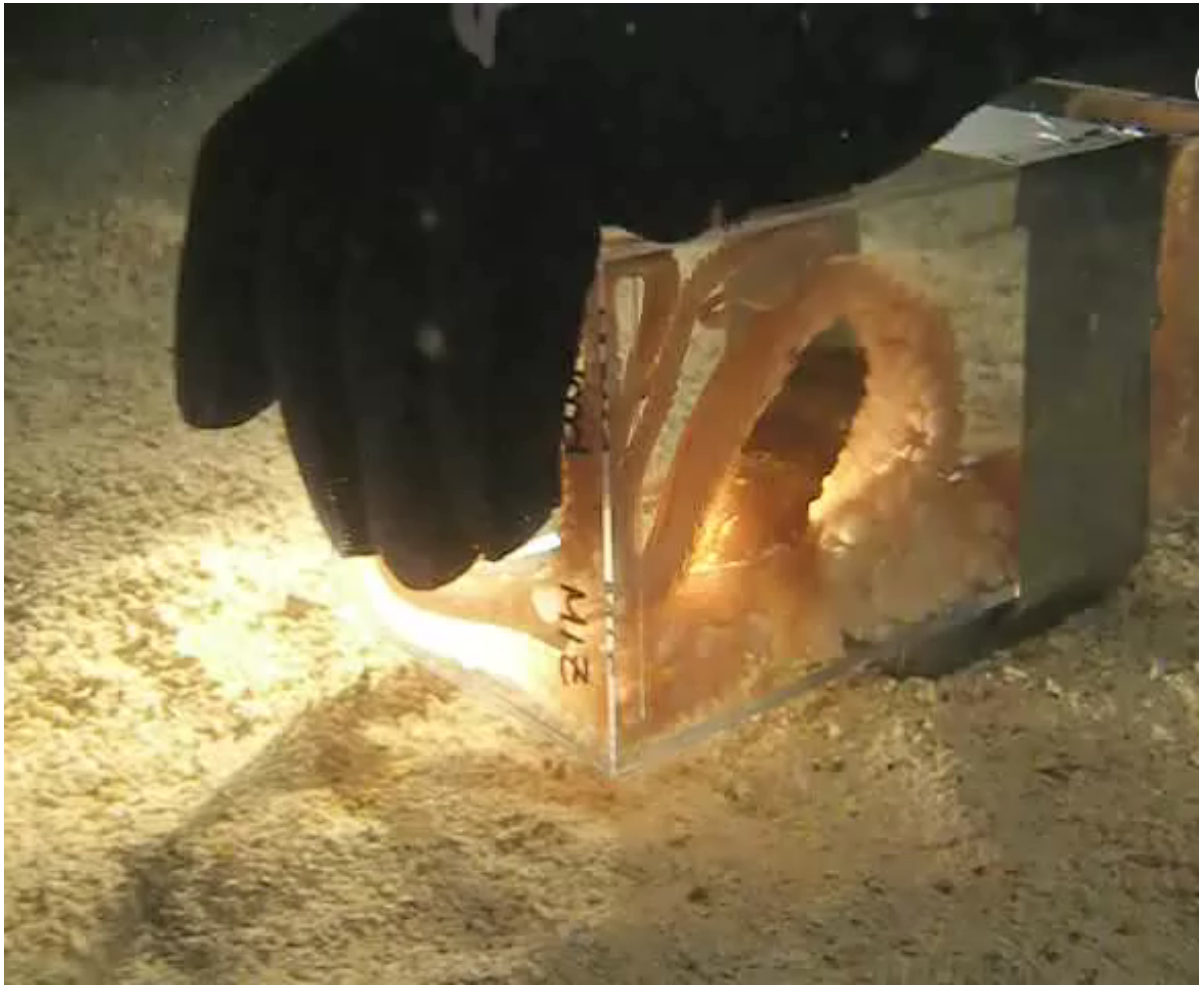
Bio-Inspiration

From Bio-Inspiration to Bio-Application



Soft, but stiffness controllable

Requirements for soft/flexible surgical robot

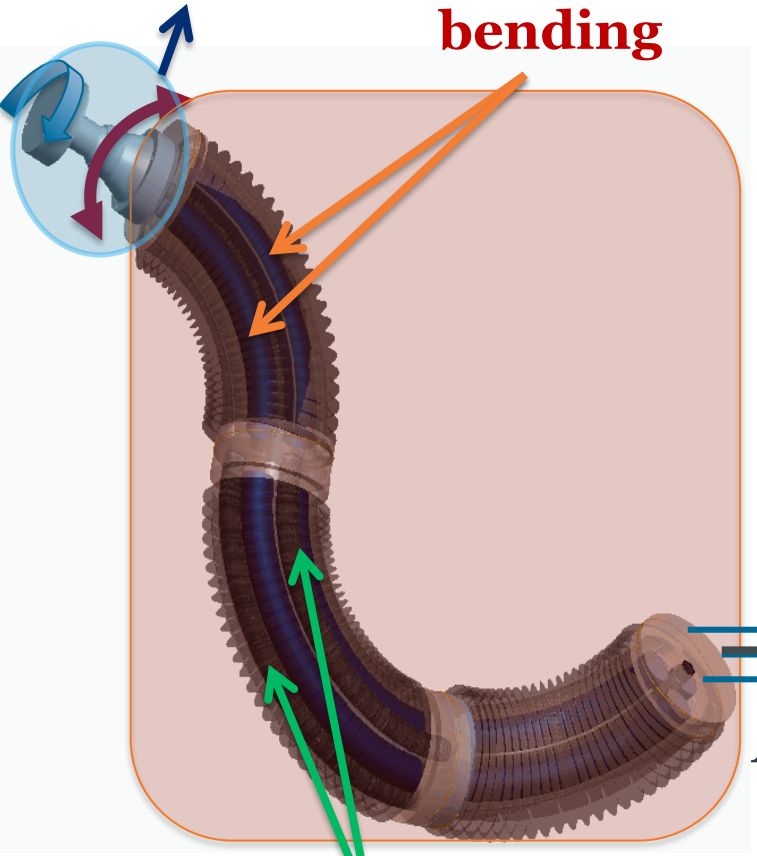
- Ability to bend and elongate to reach far and behind obstacles – to reduce repositioning tasks and simplify execution of certain tasks
- Soft (where and when required) to automatically adapt to surrounding environment without applying to high forces
- Stiff (where and when required) to apply forces at site of operation such as grasping, excising, ablation
- Control of pose
- Control of applied force
- Haptic feedback

STIFF-FLOP Manipulator Design (1)

Przemysłowy Instytut Automatyki i Pomiarów

Distal joint

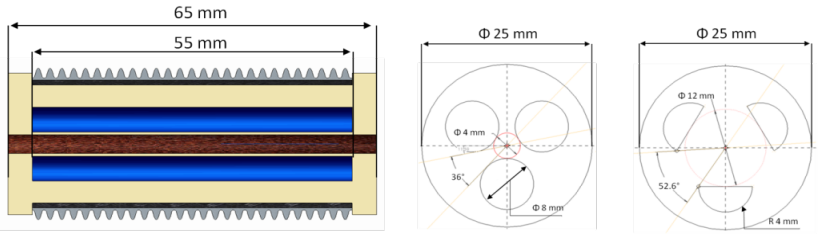
Omni-directional bending



Actuation

Stiffening system

CURRENT DIMENSIONS

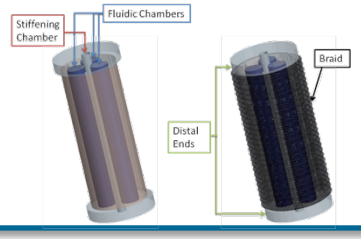


MATERIALS

- Silicone Unit: 0030 EcoFlex
- Sheath: PET
- Stiffening chamber membrane: Latex
- Granular matter: Coarse Coffee

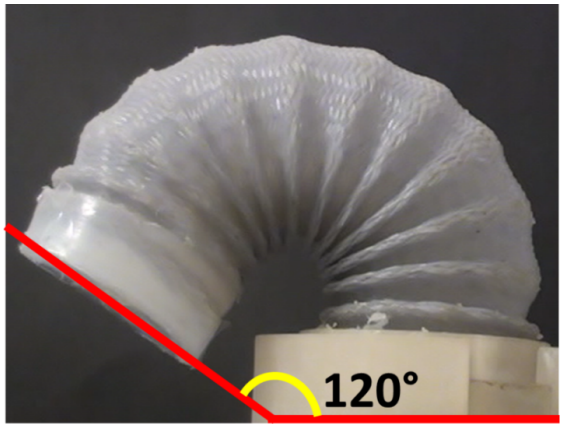
OVERALL STRUCTURE

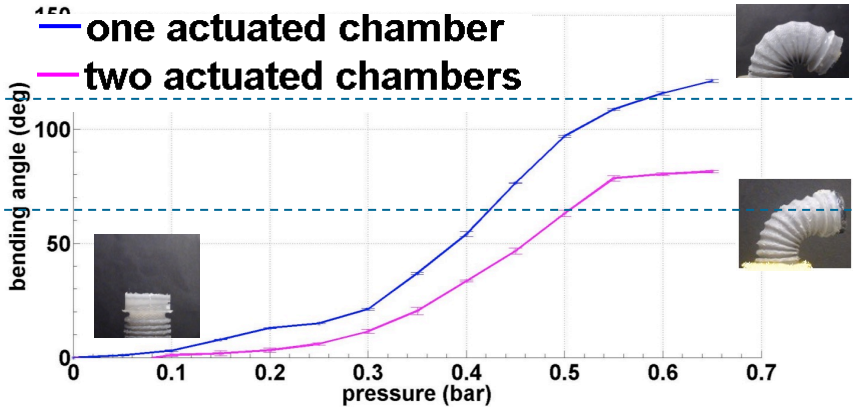
3 chambers for fluidic
Actuation
Stiffening



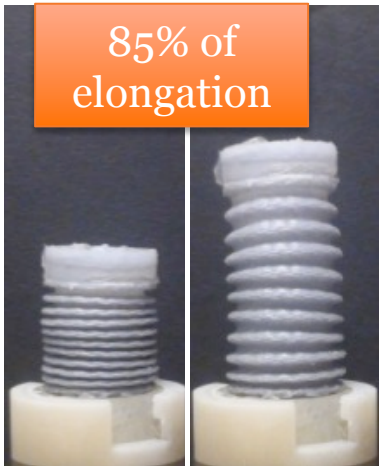
STIFF-FLOP Characterisation

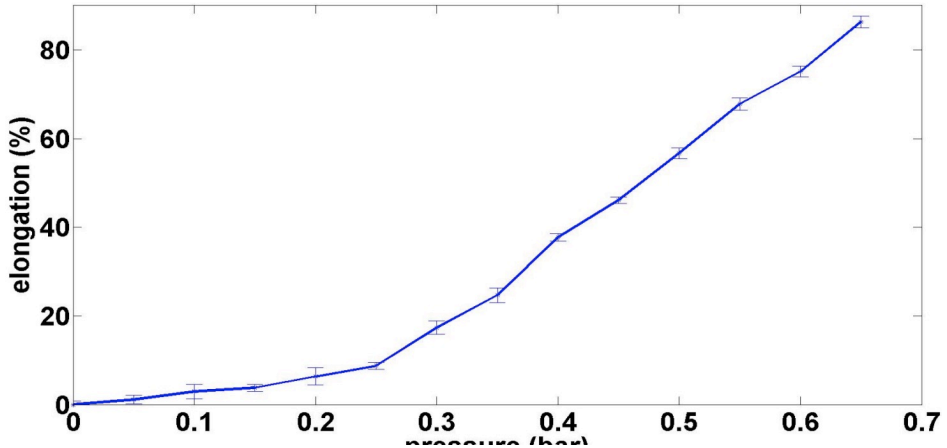
Bending





Elongation



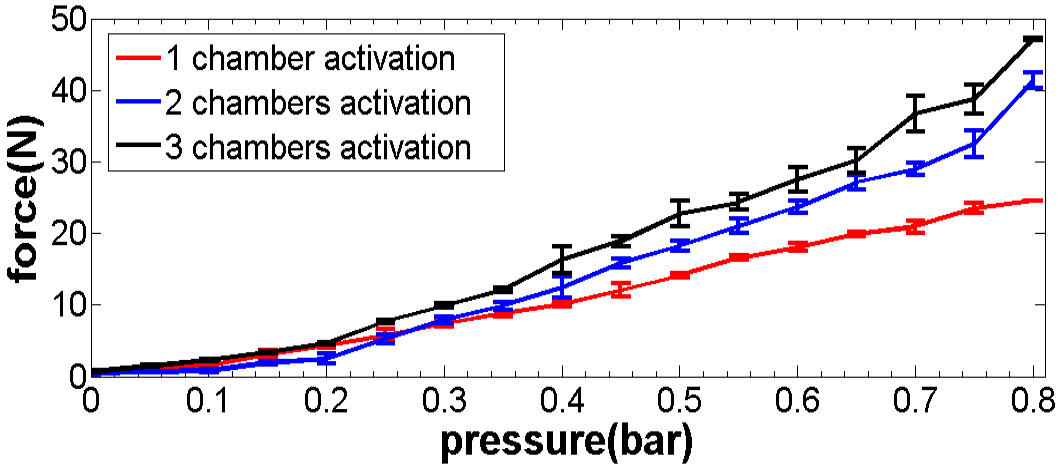


STIFF-FLOP Charaterisation

Force

Isometric conditions

ATI Mini45 load cell on the top of the module



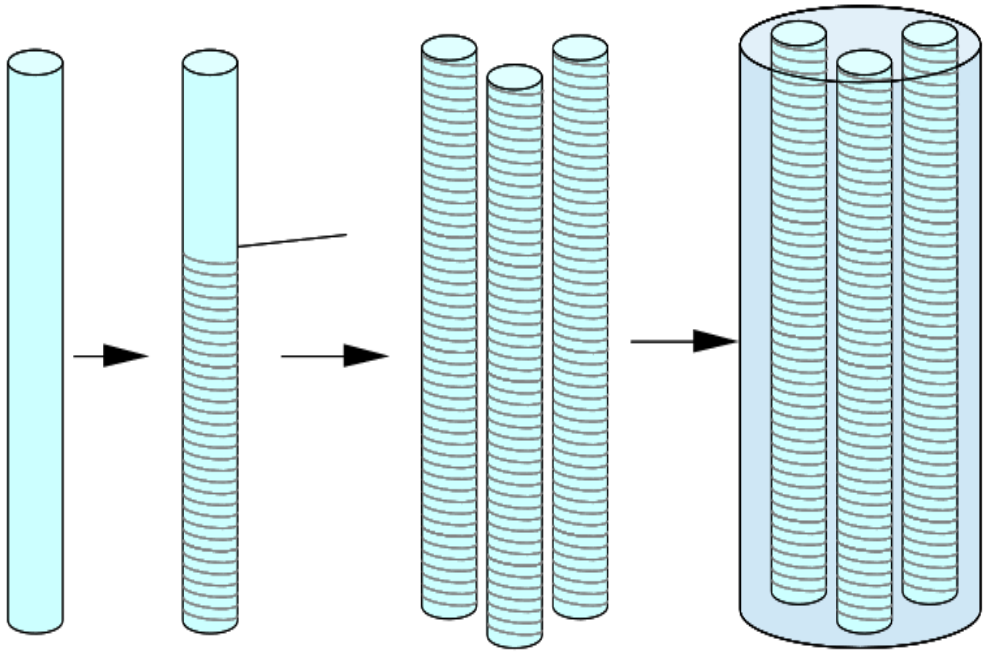
Squeezing

Due to the absence of rigid structures the module can be deformed for passing through single port laparoscopy incision

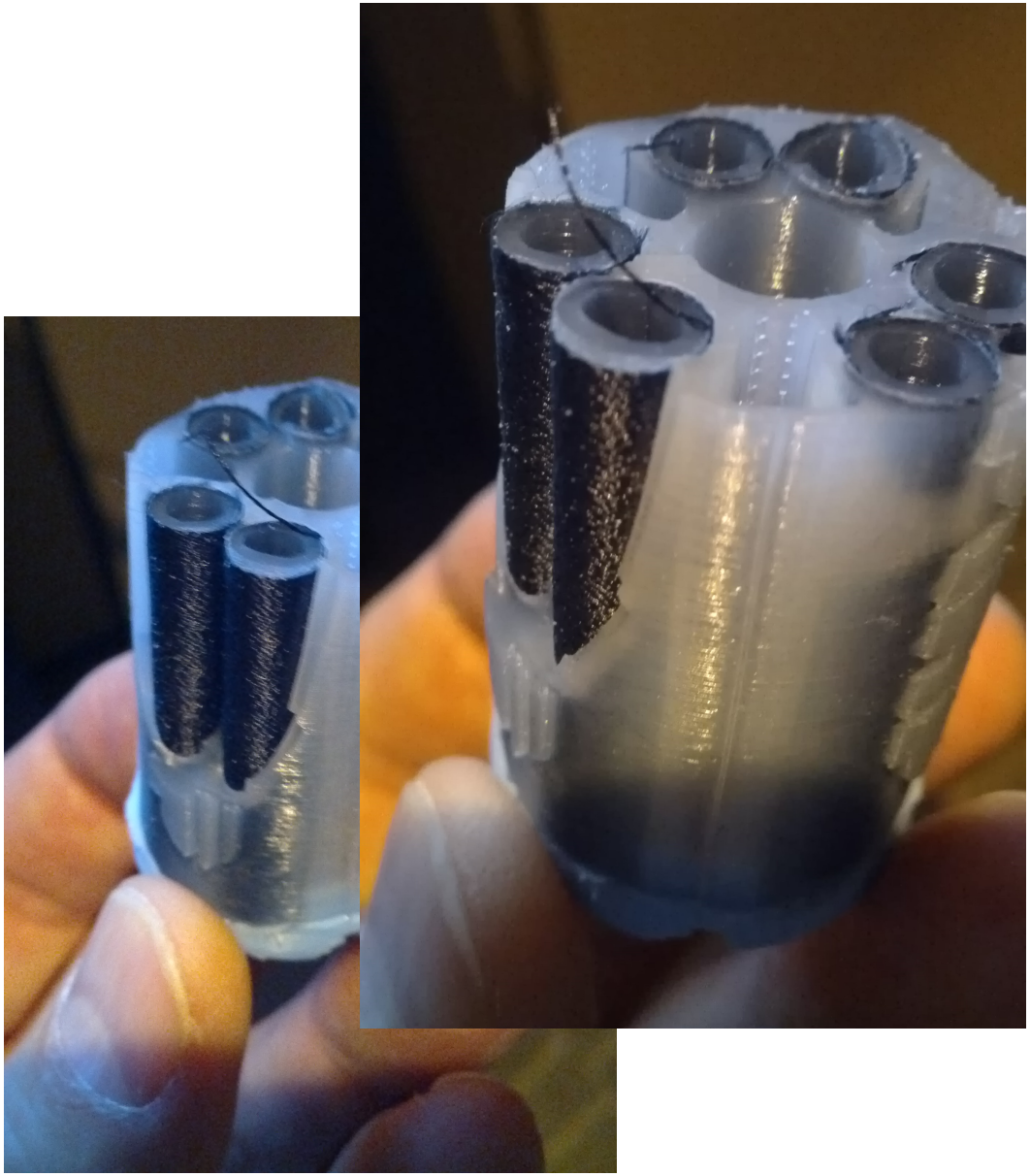
40% passive squeezing

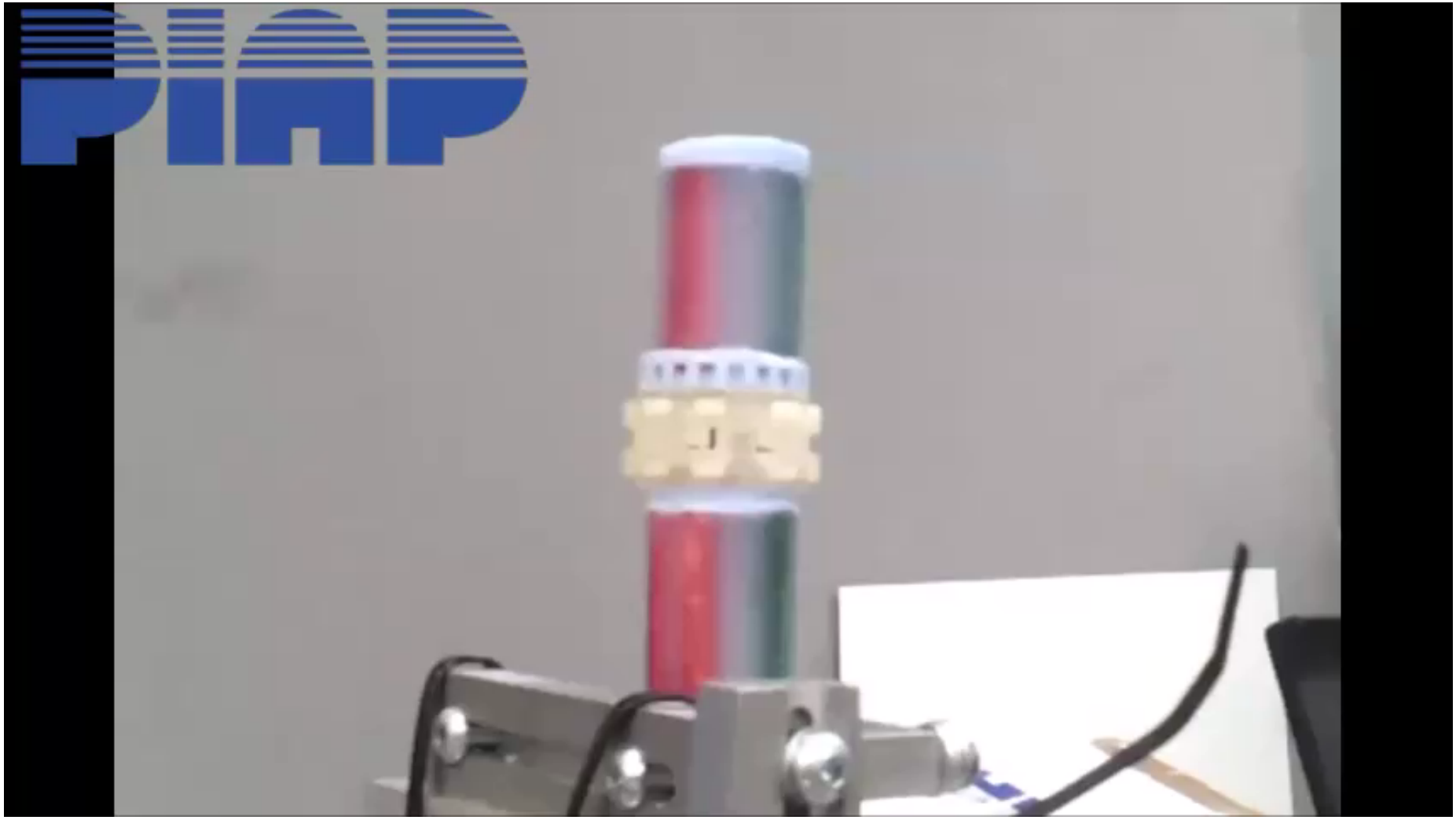
STIFF-FLOP Motion Behavior

STIFF-FLOP – Fiber reinforcement

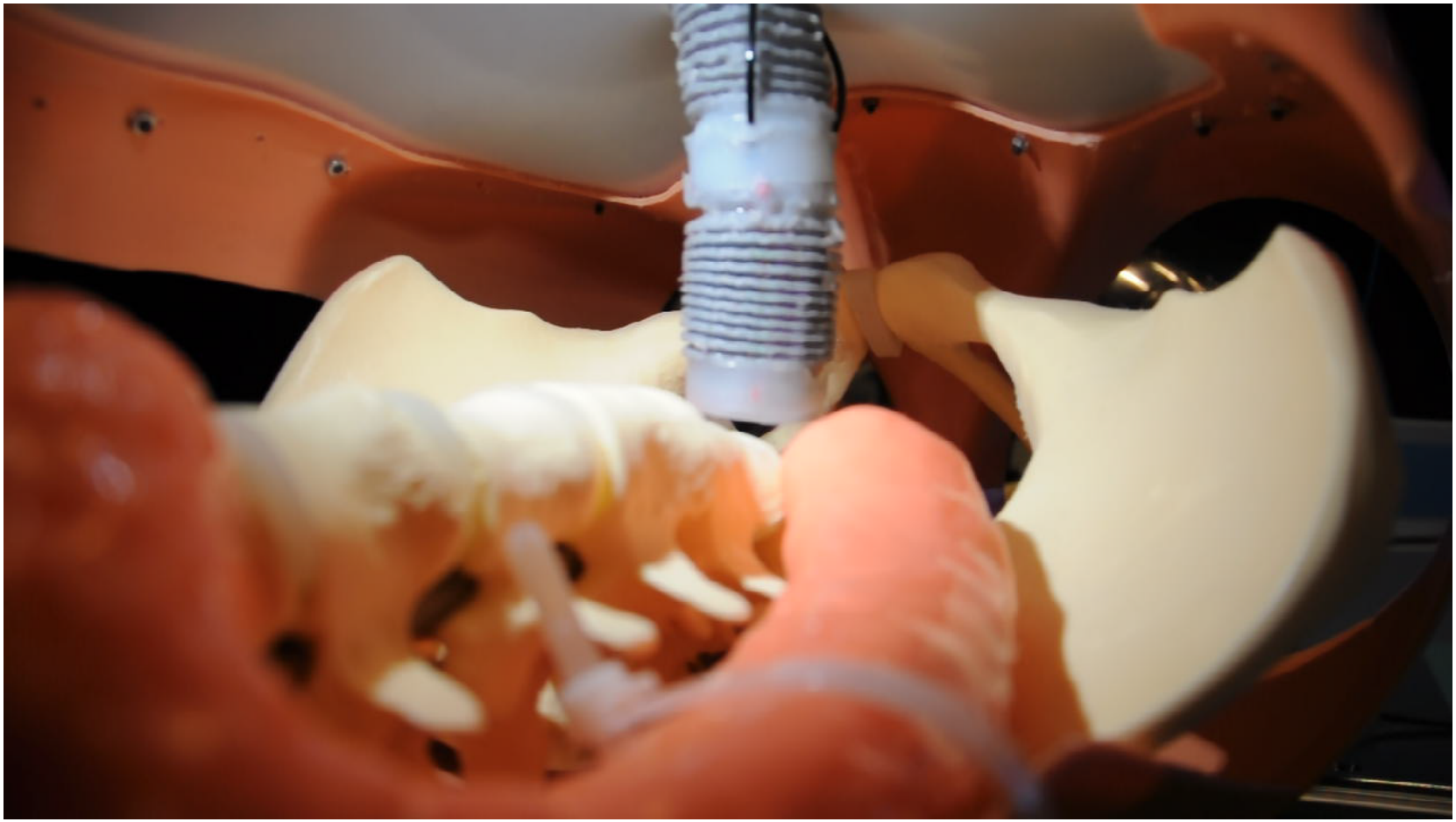


- More linear actuation
- No sensor interaction
- Radial expansion strongly limited
- No external braiding = softer robot

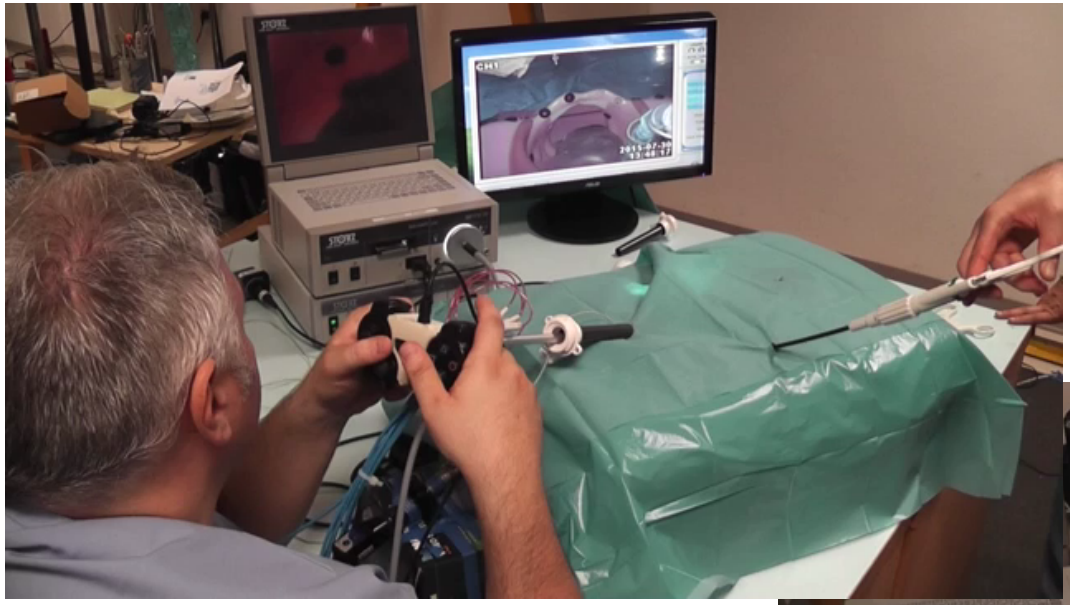


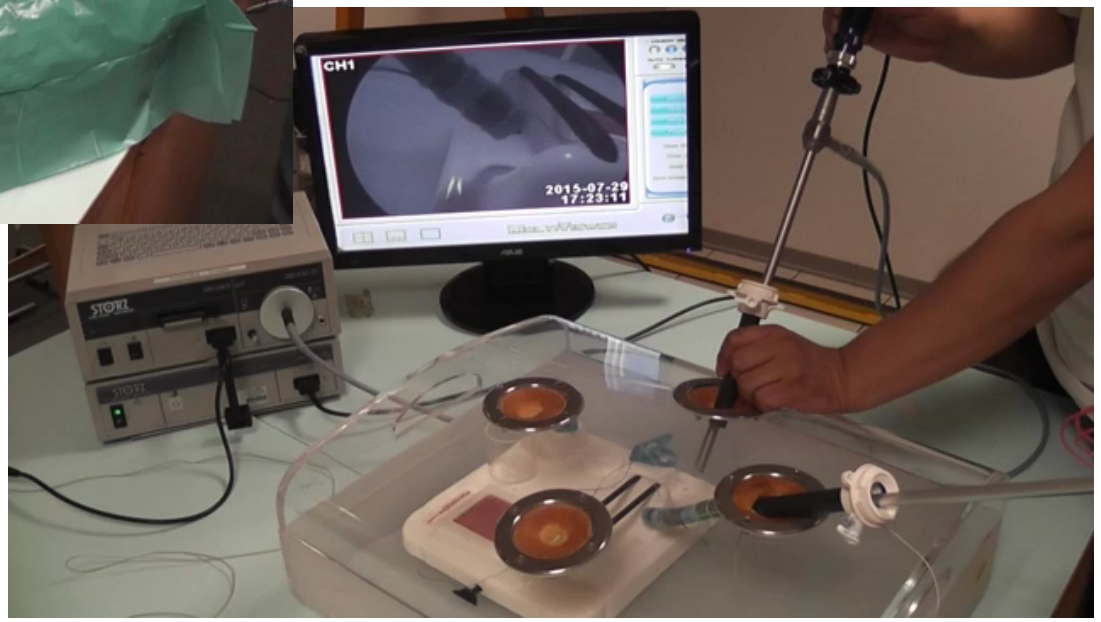

PIAP

Early prototype in phantom

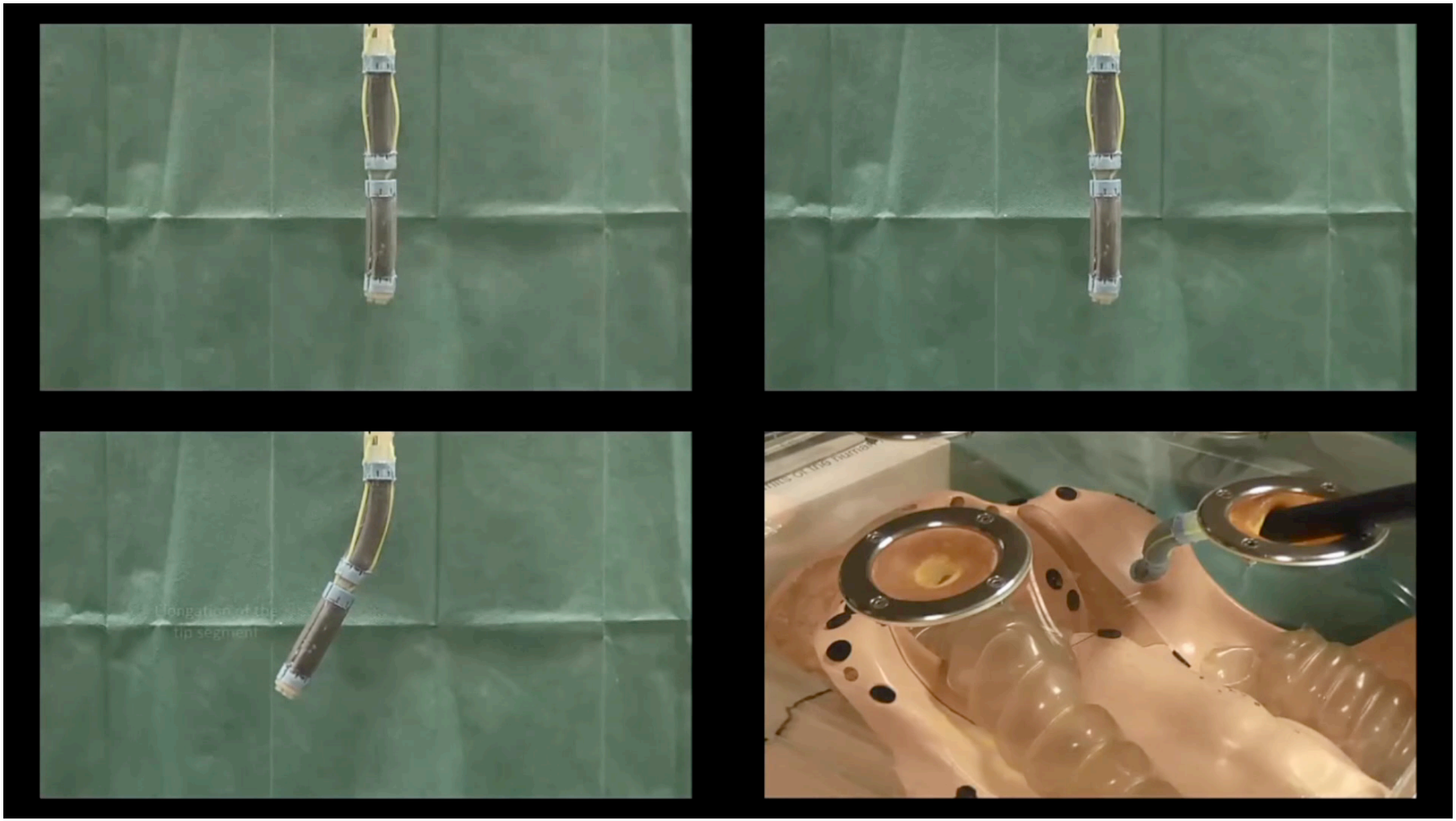


Miniaturized Prototype



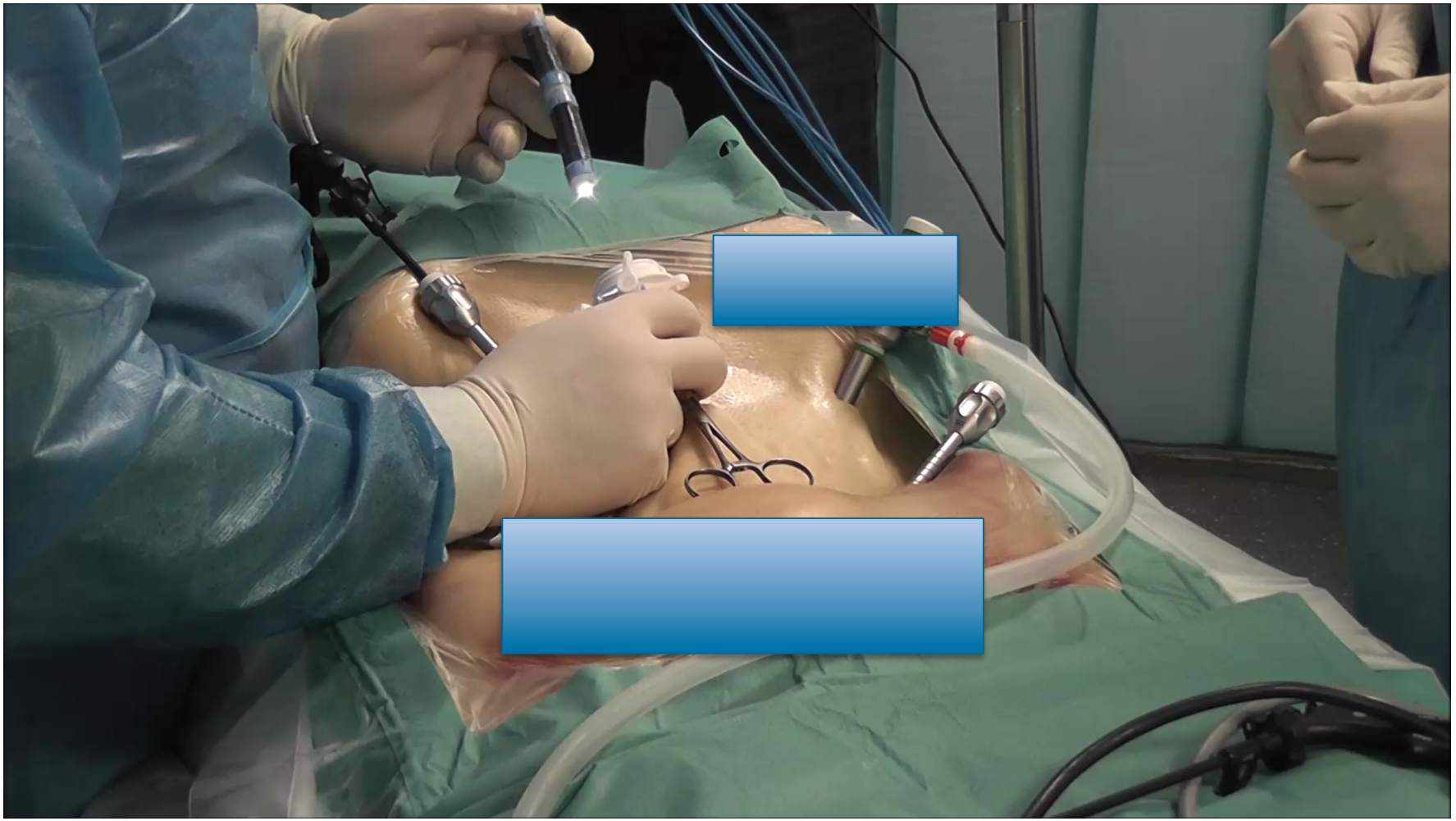


Miniaturized Prototype



Miniaturized Prototype

First in human



Inflatable, tendon-driven robots with inherently antagonistic behaviour

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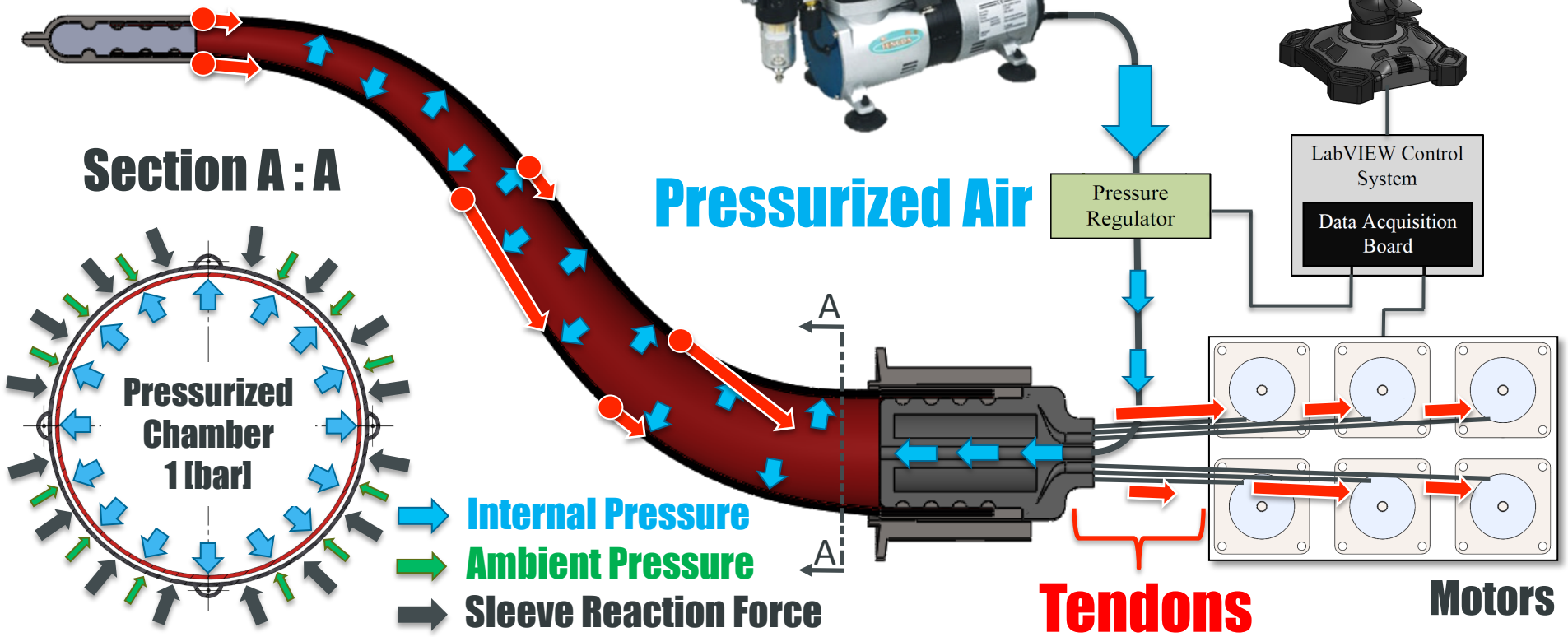
STIFF-FLOP Manipulator Design (2)

KING'S College LONDON

Push & Pull Antagonistic System



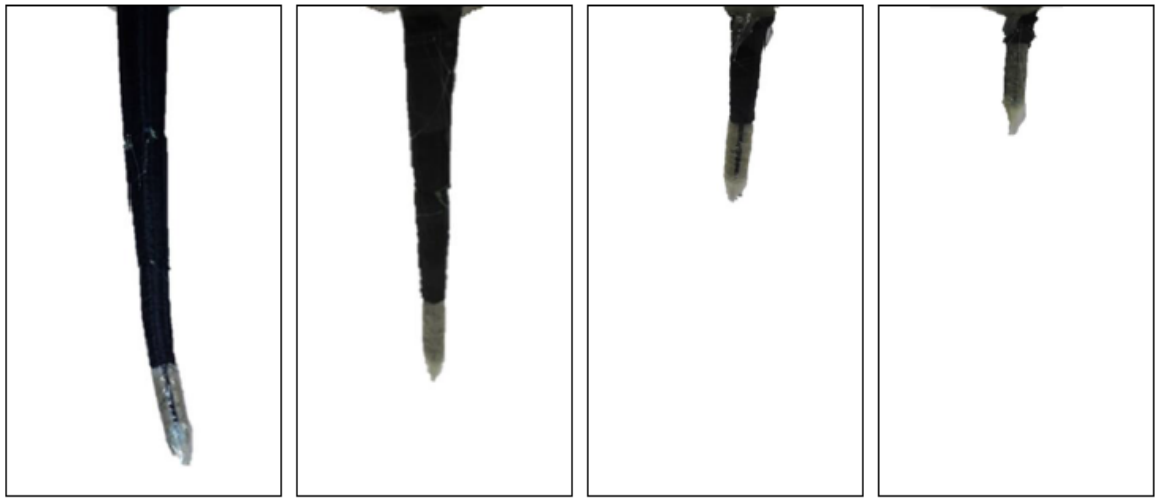
The Inflatable Arm: Steer and Shrink

Steerability

- ✓ High dexterity
- ✓ Complex body poses
- ✓ Body pose redundancy

Shrinkability

- ✓ No rigid backbone
- ✓ Access through narrow openings
- ✓ Maximized workspace



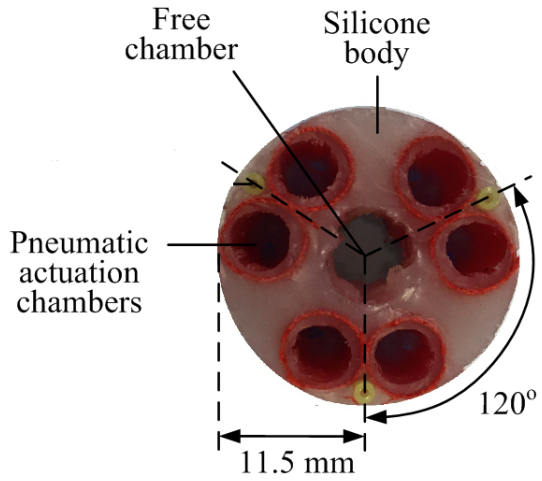
Inflation

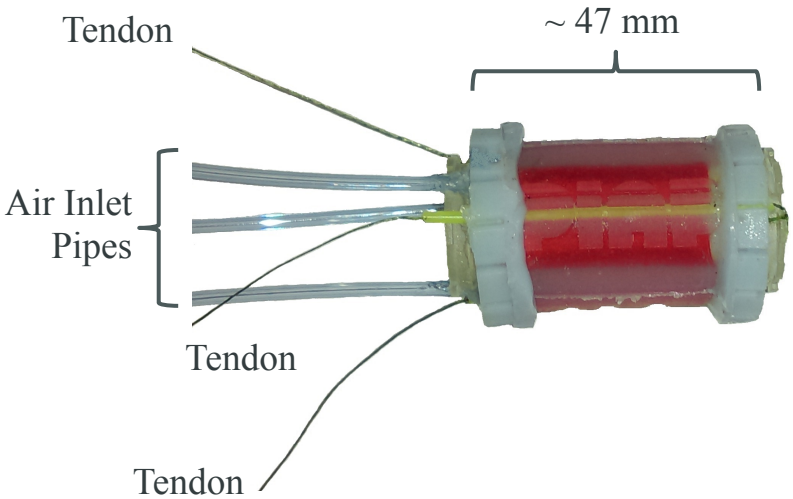
Deflation

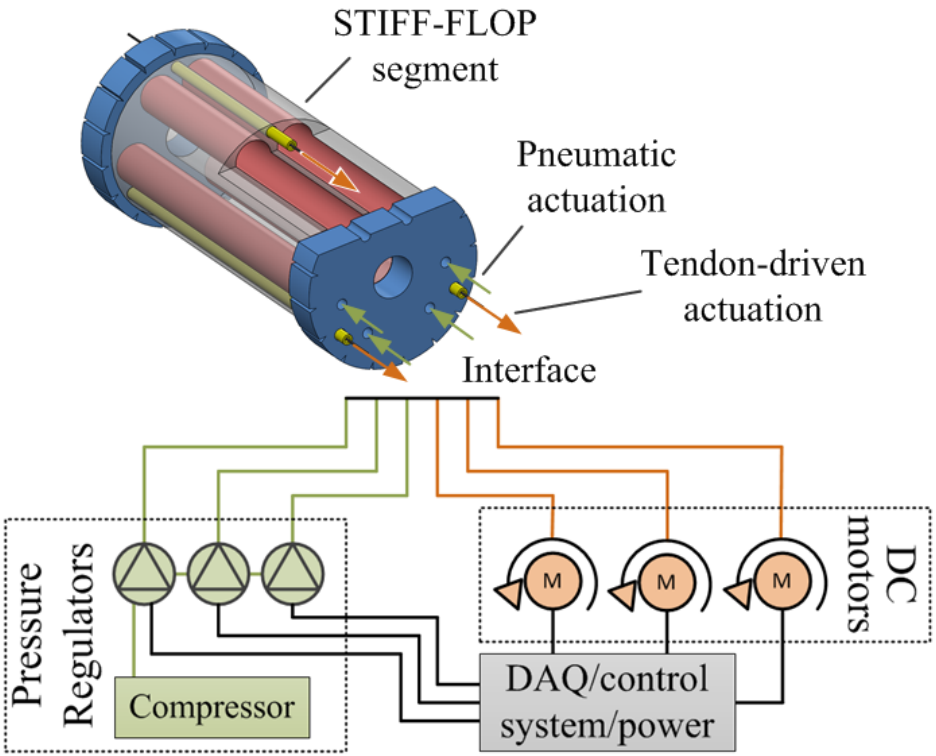
Steerability

Inflatable Robot in phantom abdomen

Hybrid fluidic-tendon robot







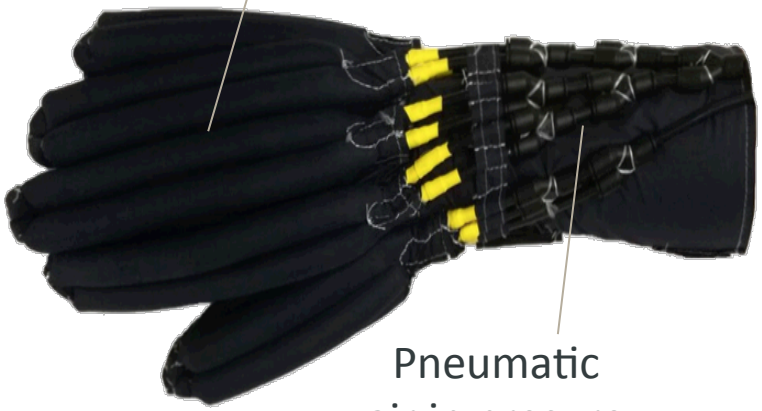
ORTHOTICS - INFLATABLE EXOSKELETON GLOVE

Wrist band

A pair of wes

Pneumatic chambers, 2 for the long fingers and 3 for the thumb

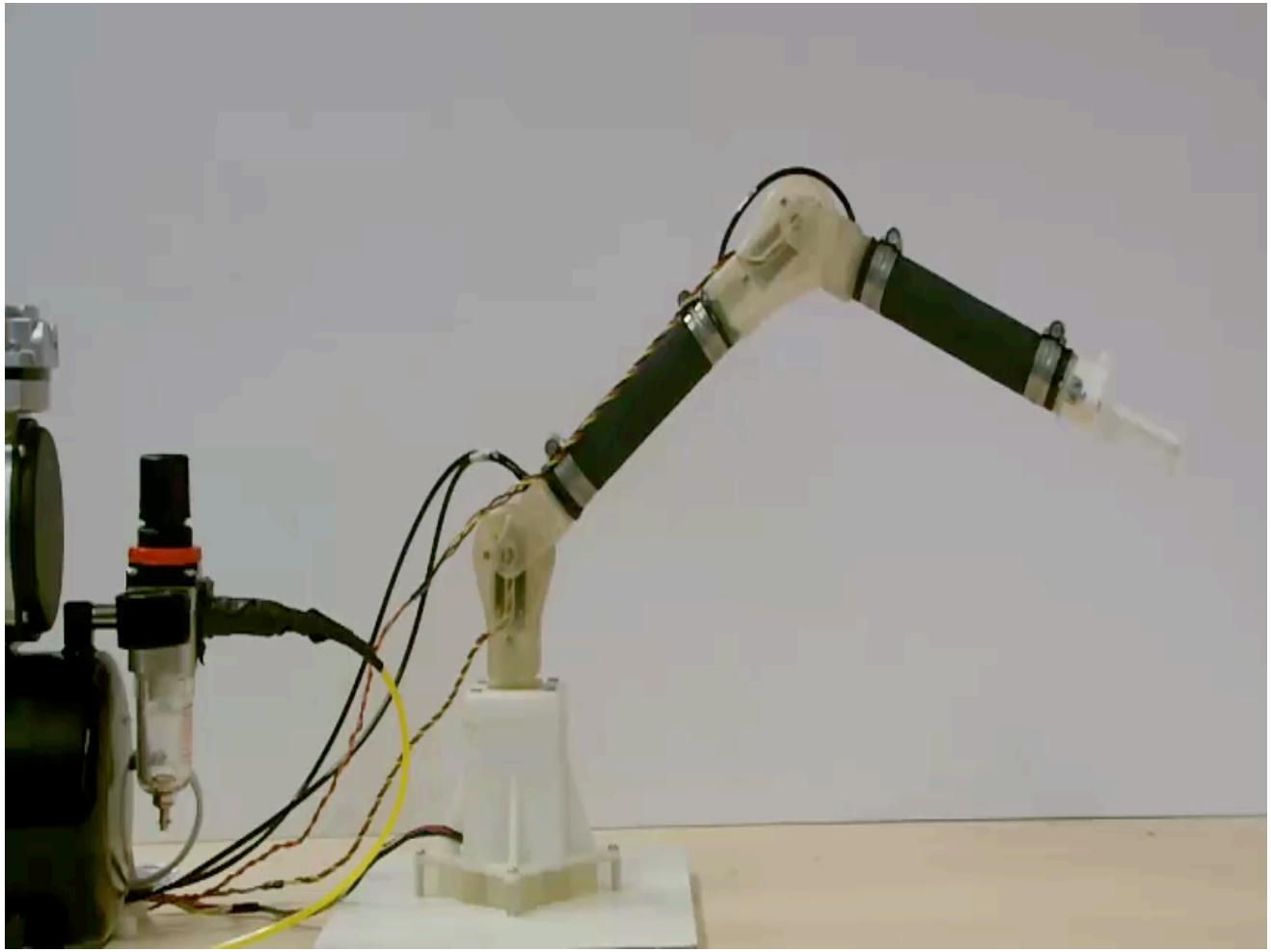
Velcro for simple and fast use



Pneumatic air in presure supply.

ORTHOTICS - INFLATABLE EXOSKELETON GLOVE

Series Elastic Link in Action for a safer Factory



FOUR BY THREE

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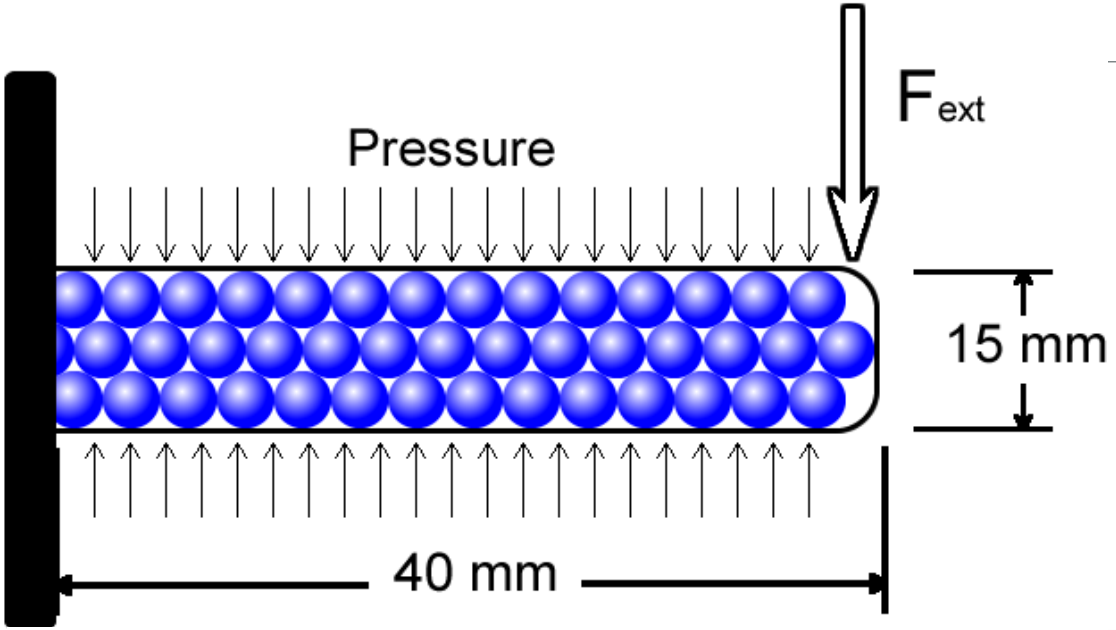
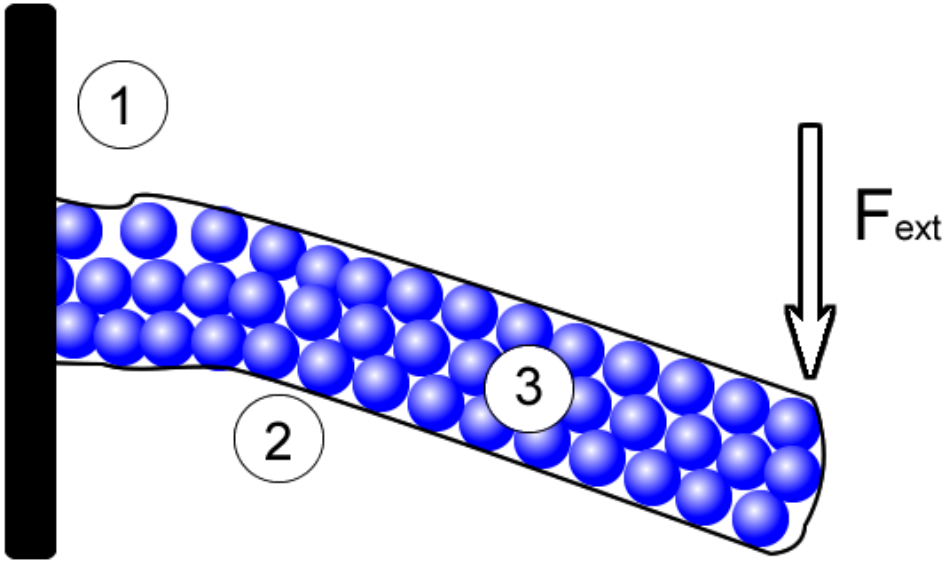
Granular jamming, to control stiffness in a soft robot

Granular Jamming to control stiffness





Bending: Experimental setup

Acting as a cantilever beam with one fixed end, the joint is deflected at the tip. The loading force is measured as the deflection increases. This process is repeated at several pressure differentials.

Region 1: Tension
Region 2: Compression
Region 3: Shear

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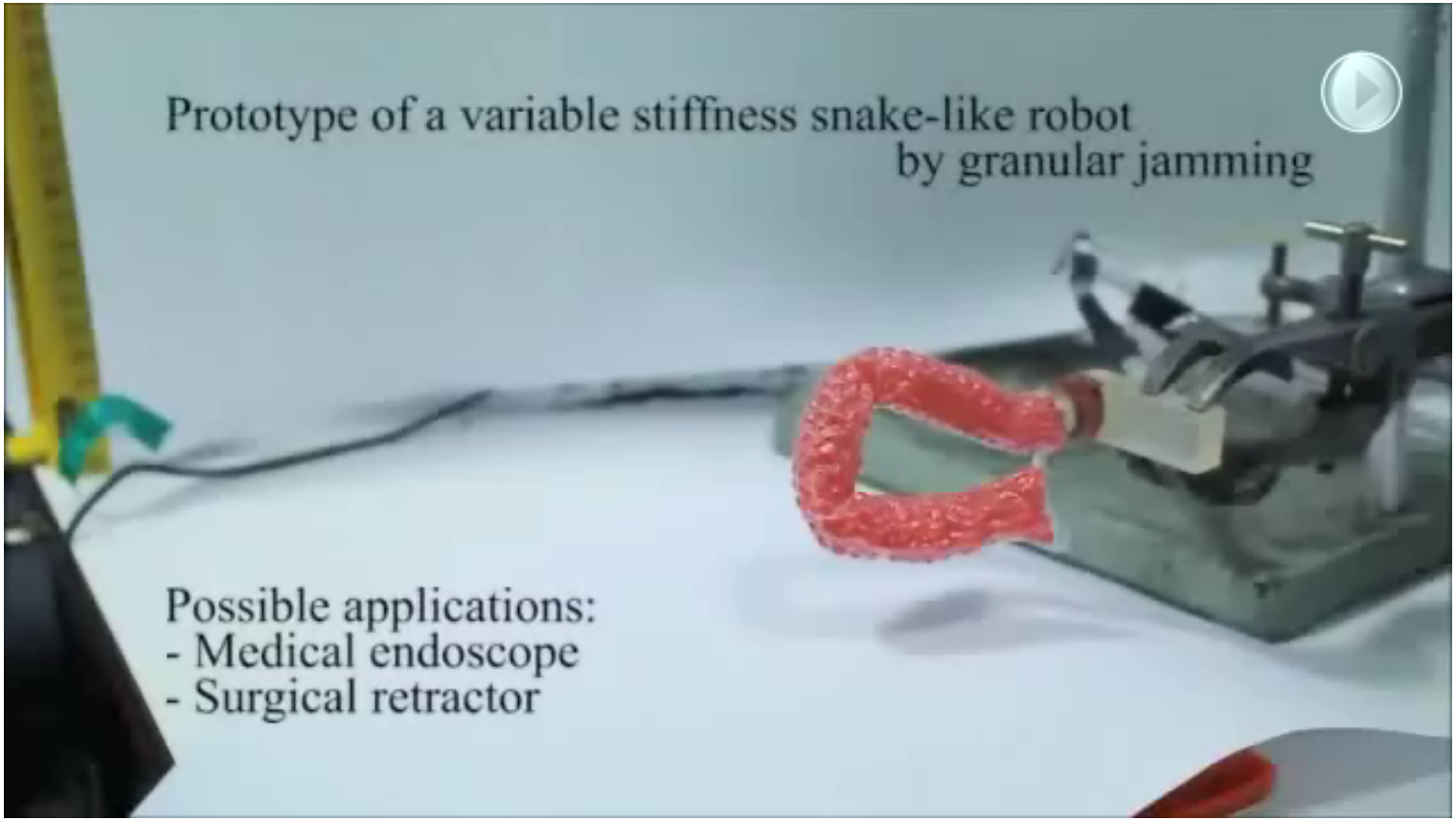
Granular Jamming to control stiffness



Granular jamming, a phenomenon where many solid grains can act as ‘fragile matter’. An externally applied stress can change a granule system from being fluid-like to solid-like.

Granular Jamming to control stiffness

Performance of integrated stiffness control

STIFFness controllable Flexible and Learnable manipulator for surgical OPerations

The work described in this video is supported by the STIFF-FLOP project grant from the European Communities Seventh Framework Program under grant agreement 287728.

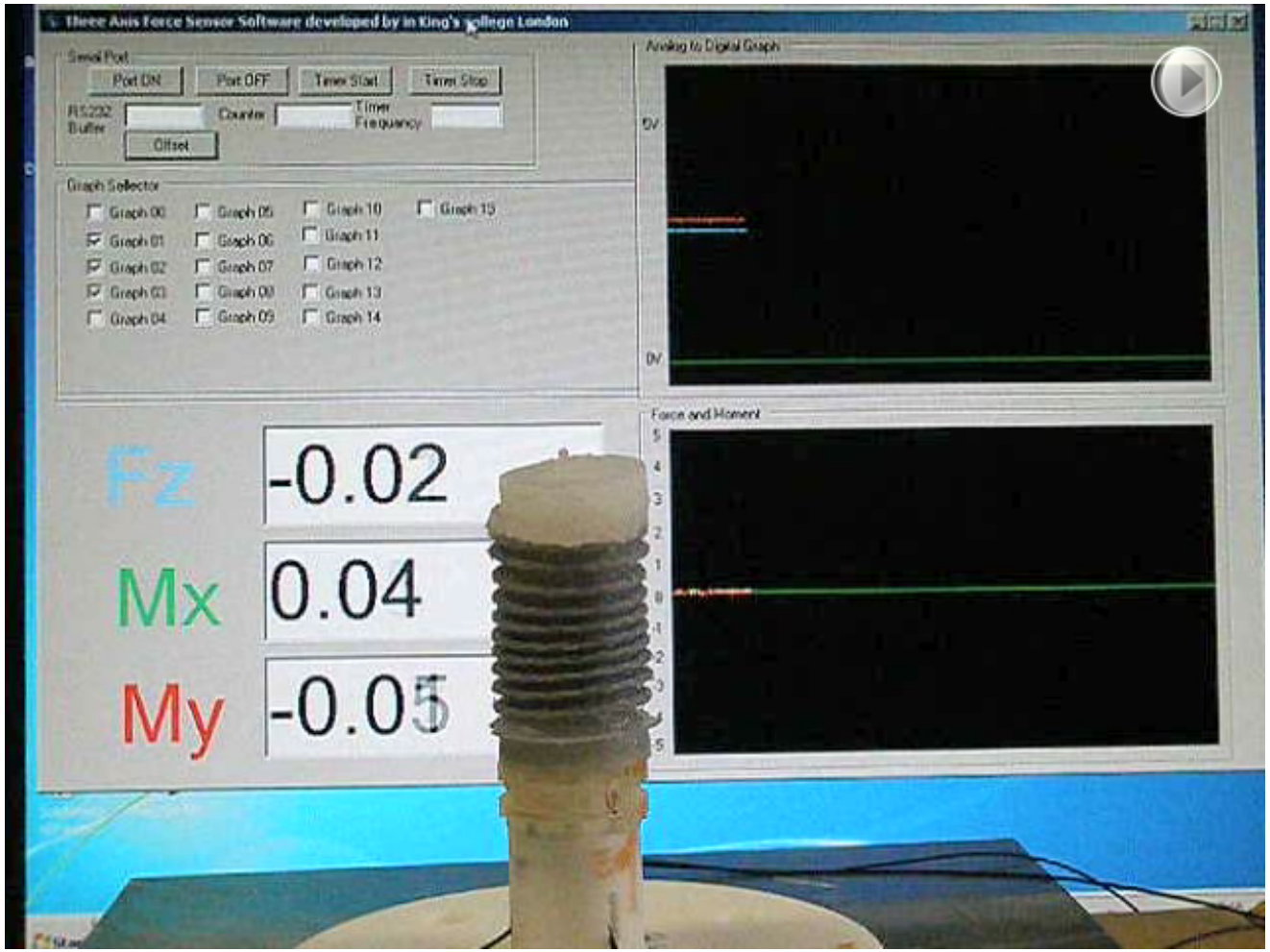
www.STIFF-FLOP.com

Soft sensing

Low-cost Force Sensor

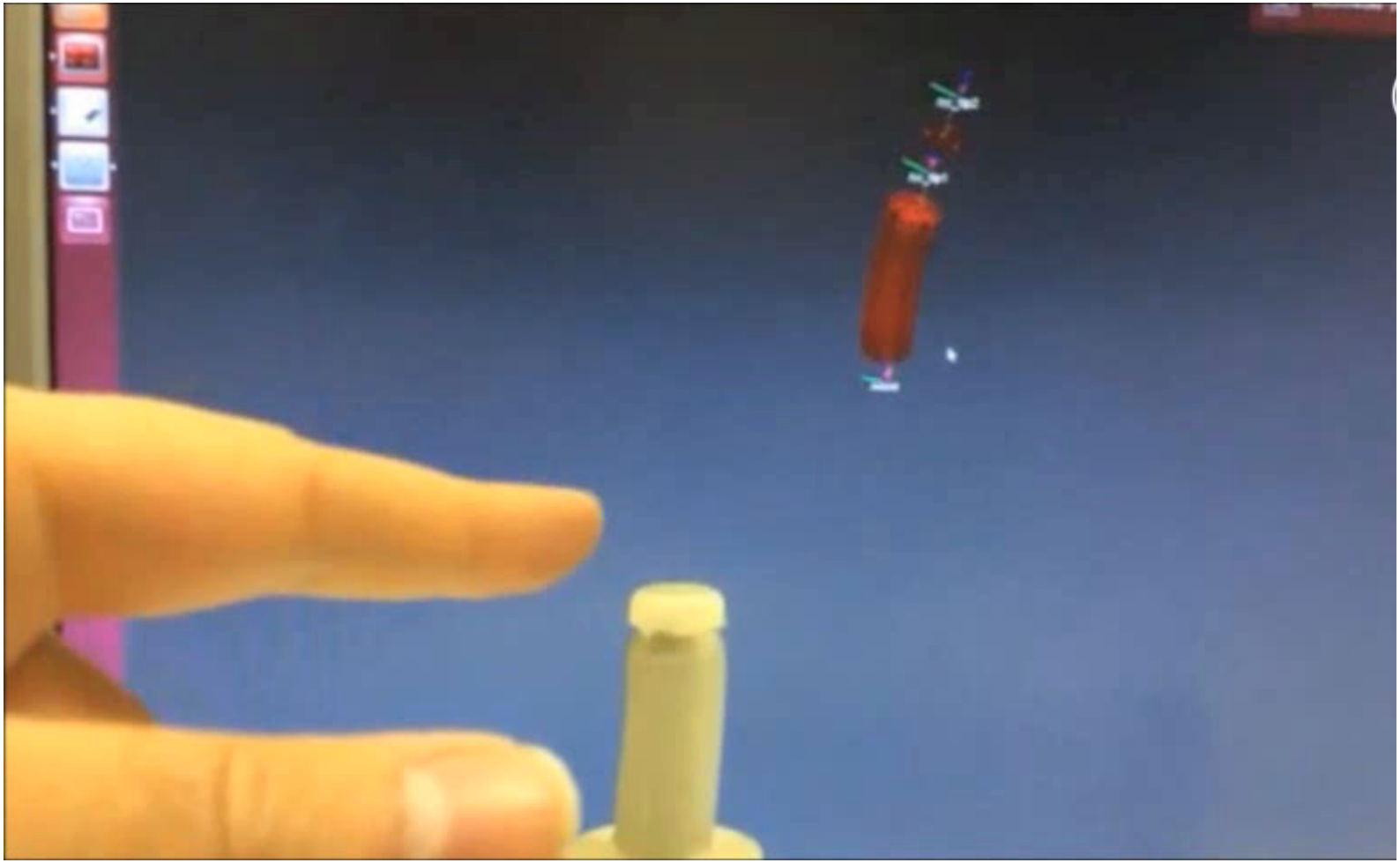
Real-time acquisition

- C Sharp GUI (Microsfot Visual Studio)
- F_{sampl} = 50 Hz
- Single segment STIFF-FLOP arm



STIFF-FLOP – Pose Sensing using fiber-optic sensor

STIFF-FLOP – Pose Sensing using yarn sensor



Challenges

- Floppy to Stiff – Stiff to Floppy?
- Motion Control
- Sensing in a Soft Structure
- Integration
- Miniaturisation

STIFF-FLOP (Partners)

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UNIVERSITÄT SIEGEN

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Shadow Robot Company

Fundacja Rozwoju Kardiochirurgii
im. prof. Zbigniewa Religi

EAES
European Association for Endoscopic Surgery

The Hebrew University of Jerusalem

tecnalia
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THANK YOU

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