ME 254, Lecture 3

Compliant mechanisms —applications

G. K. Ananthasuresh

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What are the applications of compliant mechanisms?

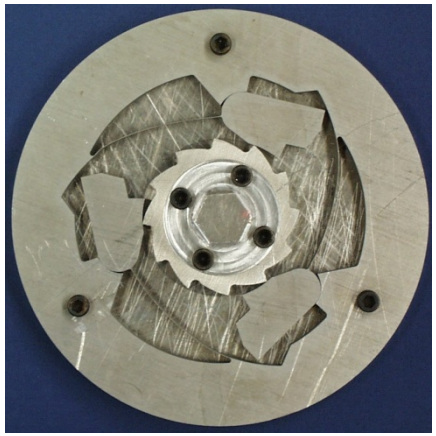
- The question in a sense is moot.
  - Compliant mechanisms can be used *wherever* conventional mechanisms are used.

Applications areas

- Consumer products
- Accessories in machinery and appliances
- Precision mechanisms
- Micro and nano systems
- Smart material-based systems
- Aerospace
- Biomedical
- Automotive
- Robotics

And more and more and more…

Real applications



Gahring and Ananthasuresh

Prof. Larry Howell
Brigham Young University

Over-running and one-way clutches

These are good wheels!

Flattening of tire
under loading

Non-pneumatic tire from IISc.

ME project report, G. Bhargav, 2008.

Flattening of tire under loading in *tweel*, an experimental design made by michelin and inspiration for this project

Tweel from Michelin.

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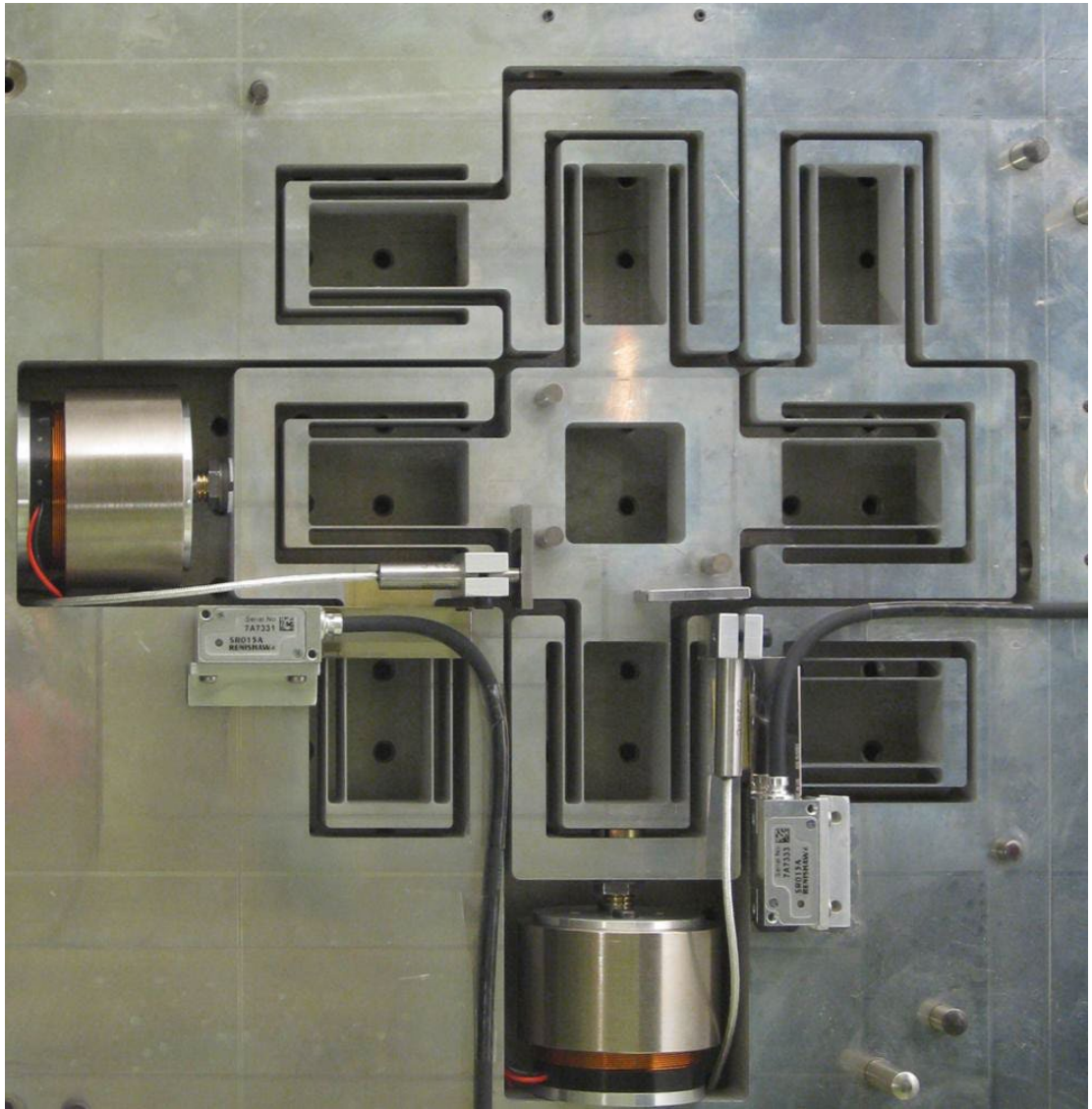
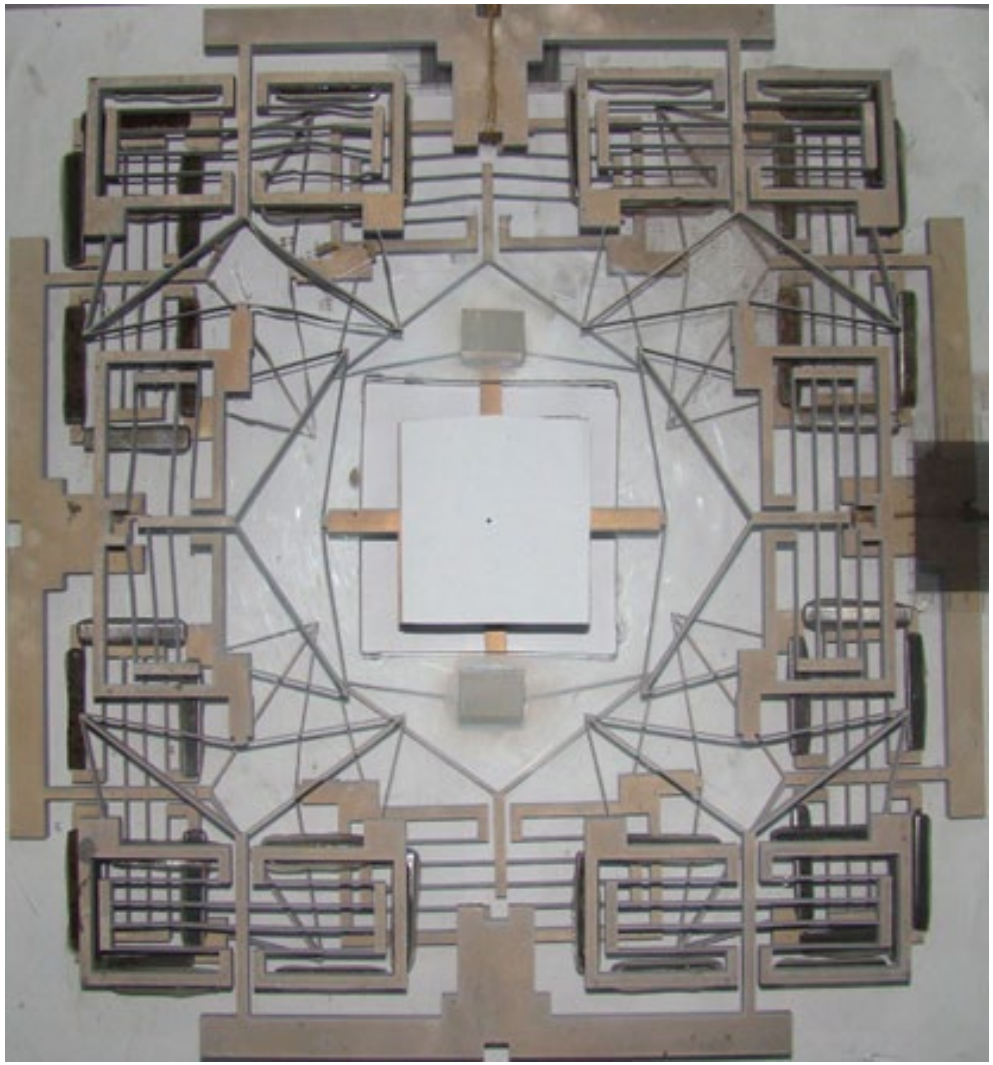
Similar thing elsewhere…



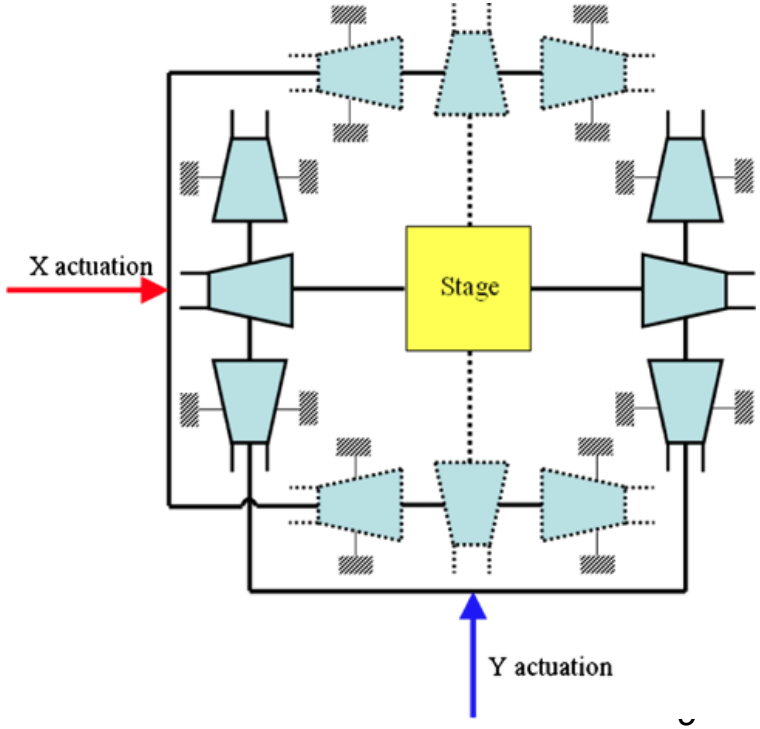
HiperNaP LLC, USA

XY stage with enhanced range of motion



Dinesh Mane, 2010

Patent granted, 2016.



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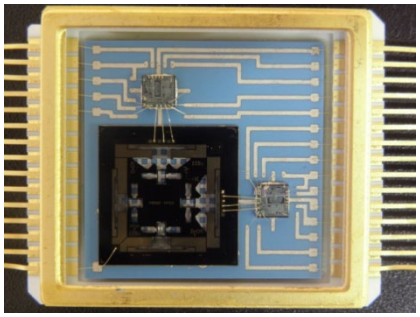
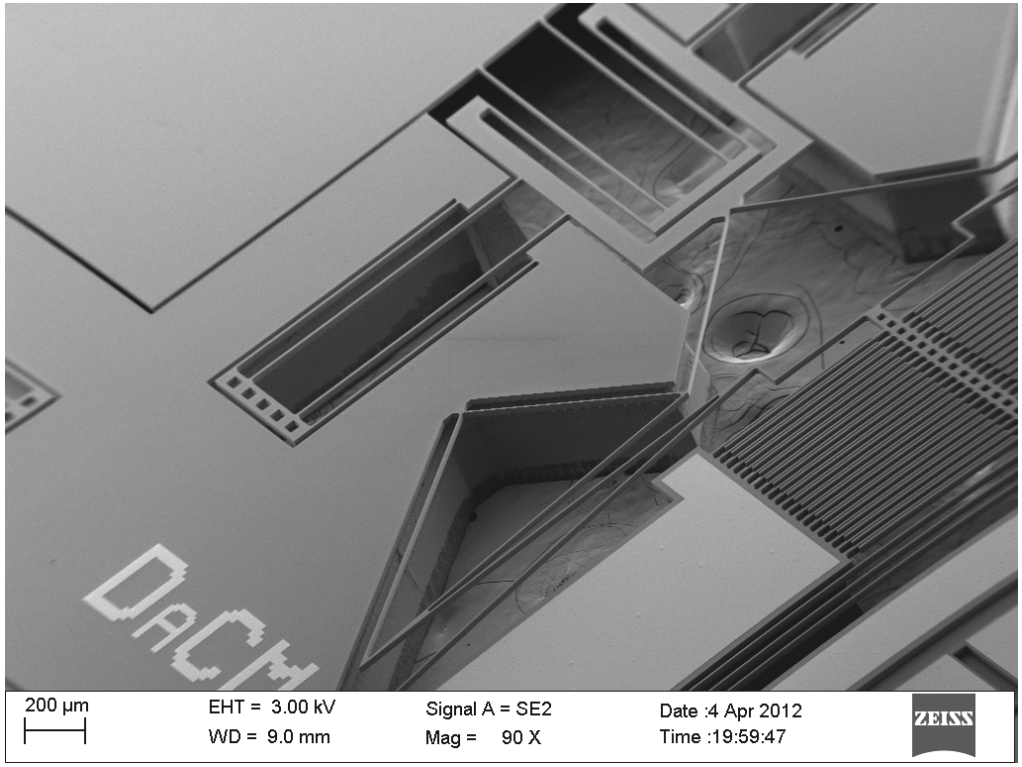
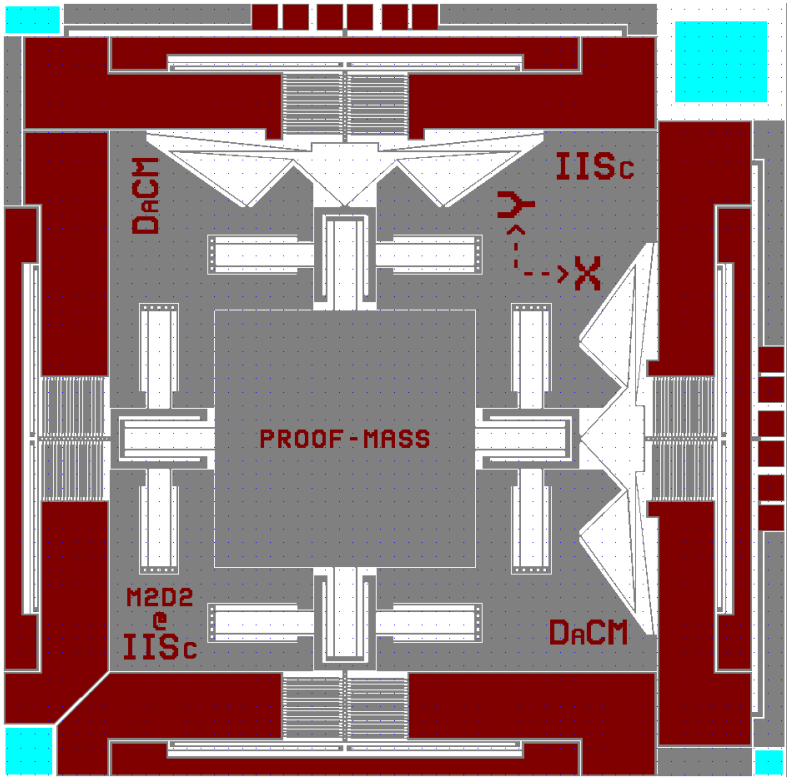
Micromachined accelerometers

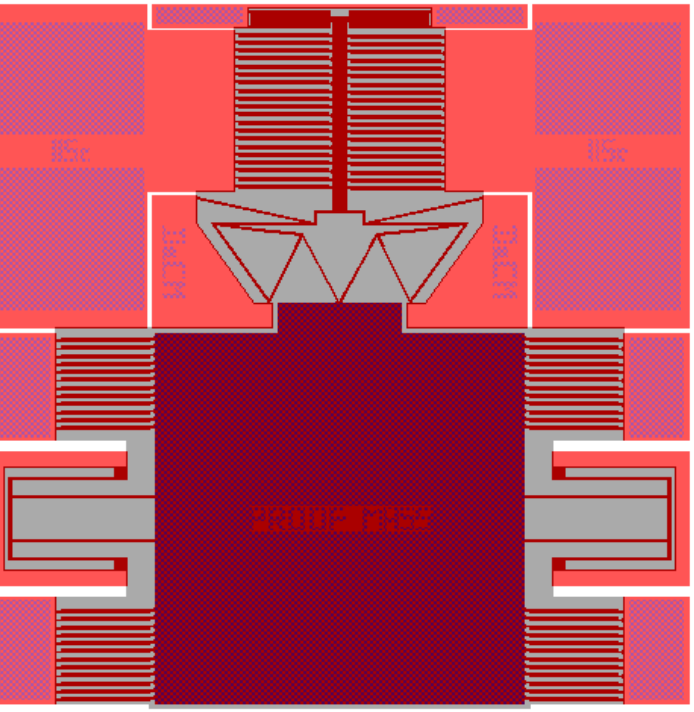


Sambuddha Khan (PhD@IISc)

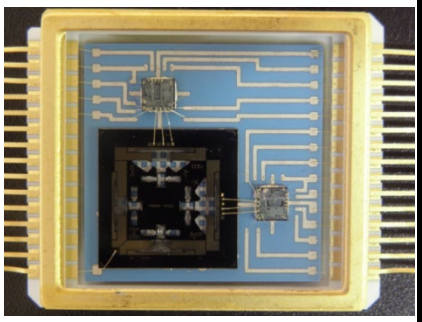


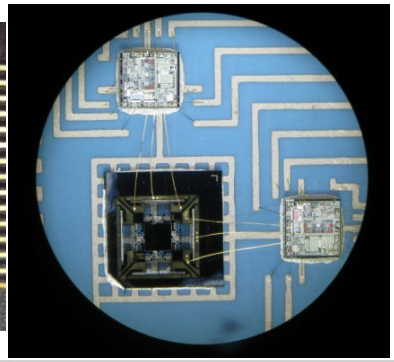


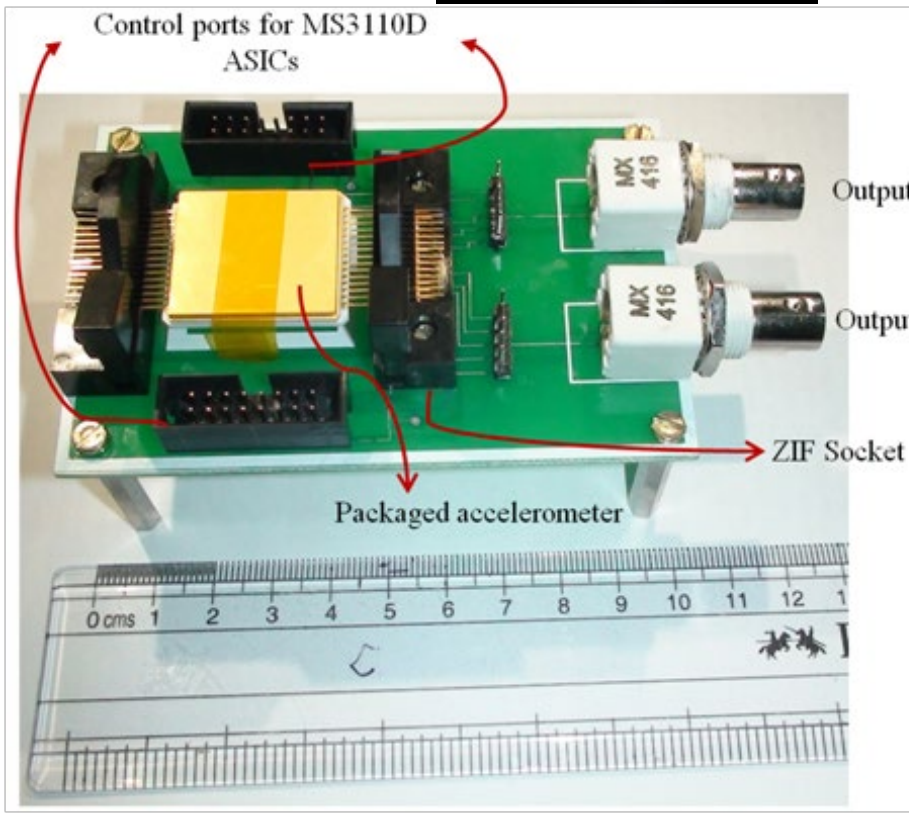
Improved micromachined accelerometers

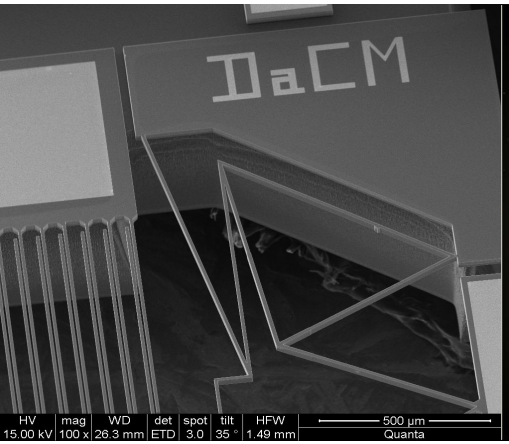


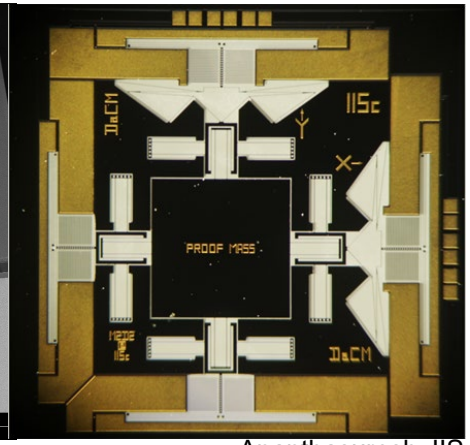
With Sambuddha Khan



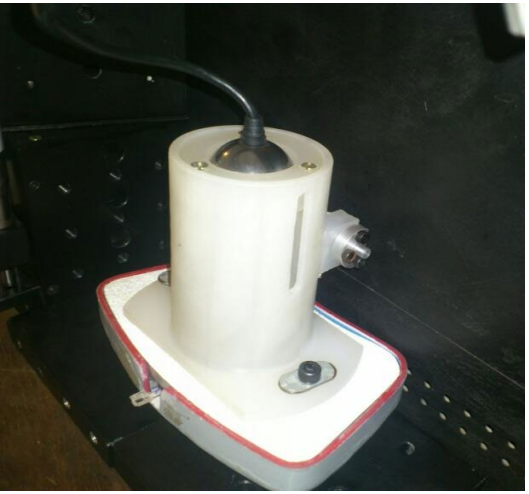


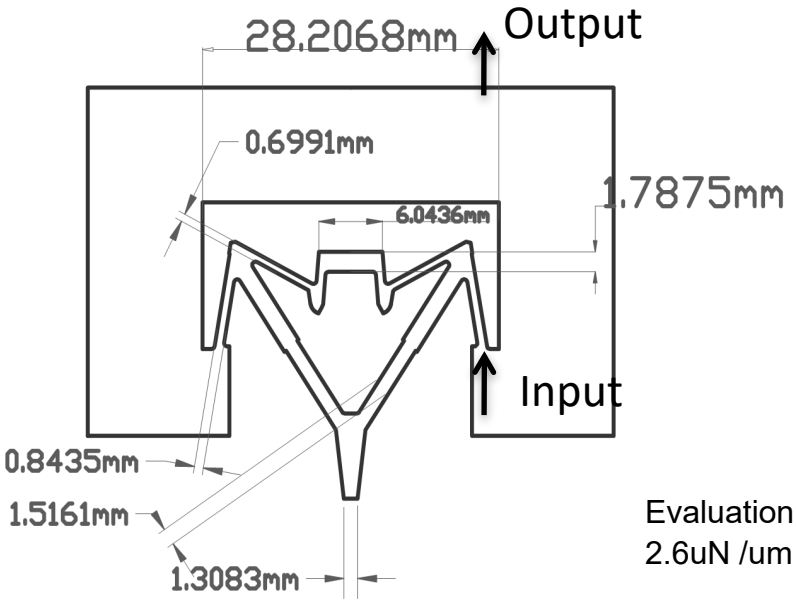


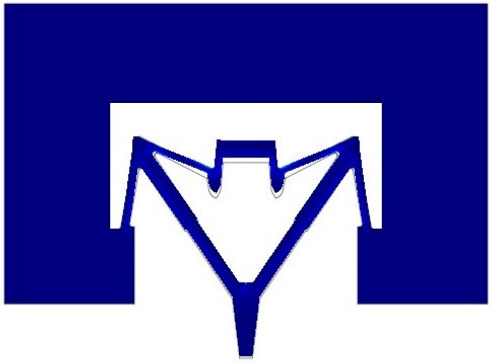




Micron: a force sensor







Evaluation: effective stiffness of 26.N/m or 2.6uN /um

~2 μN resolution
~ 1 mN range

Baichapur, Bhargav, Gulati, Maheswari, and Ananthasureh, 2012

MicroN

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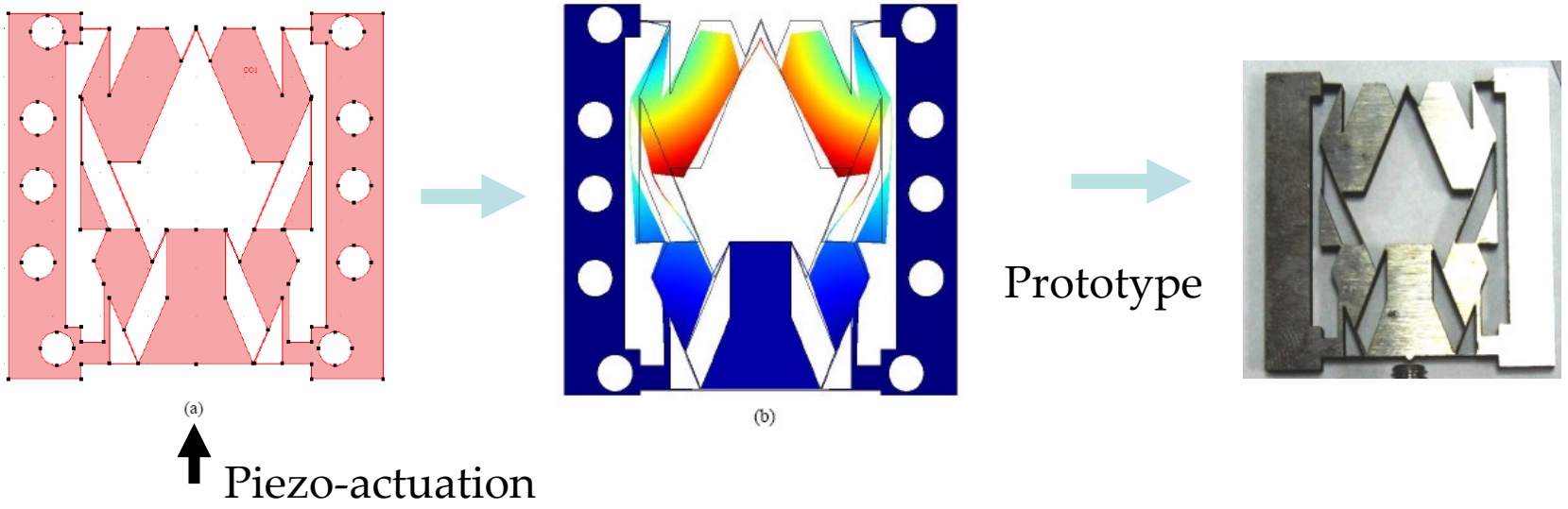
And more and more and more…

Smart material-based devices

Displacement-amplification compliant mechanism



Krishnan, G., Bharadwaj, S., Dinesh, P., Panchal, K., and Ananthasuresh, G.K., 2006

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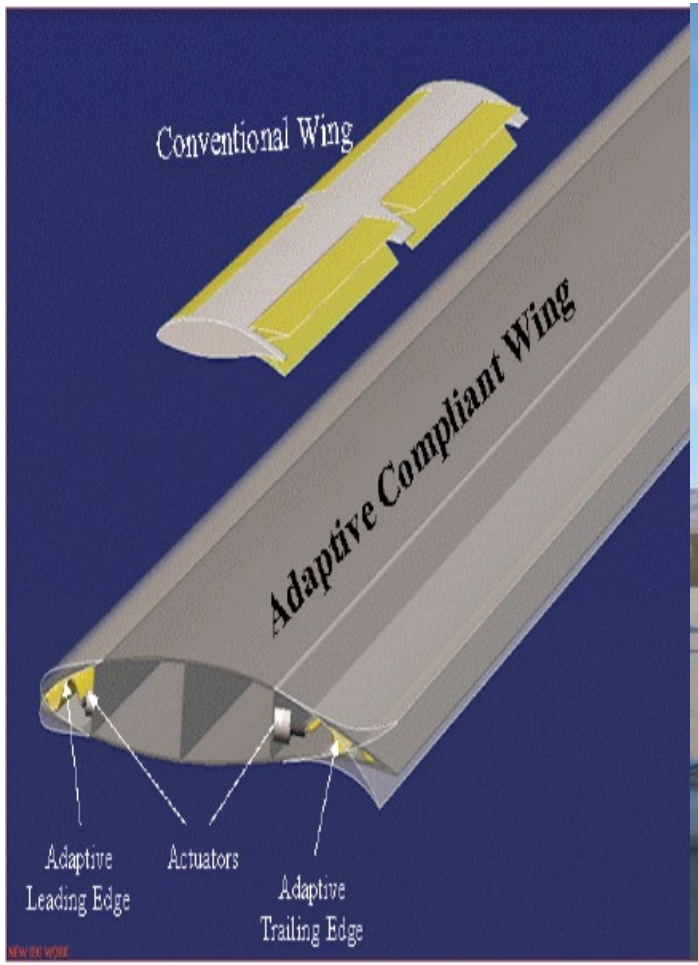
And more and more and more…

Mission-adaptive compliant wings



Prof. Sridhar Kota, University of Michigan

Morphing wing surface

WITH ELASTIC DESIGN, flexible, morphing surfaces can replace rigid wing flaps (*1*), windshield wiper frames can be molded from single pieces of material (*2*), and one chunk of plastic can do the work of a conventional stapler's nearly two-dozen parts (*3*).

Shape-shifting Things to Come

Sridhar Kota

May 2014, ScientificAmerican.com

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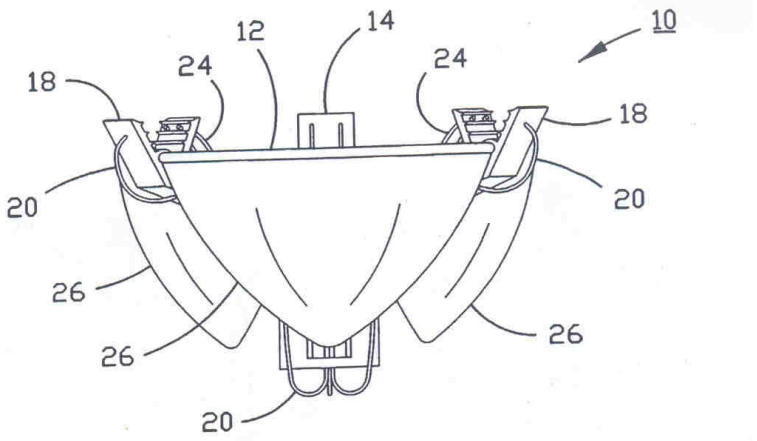
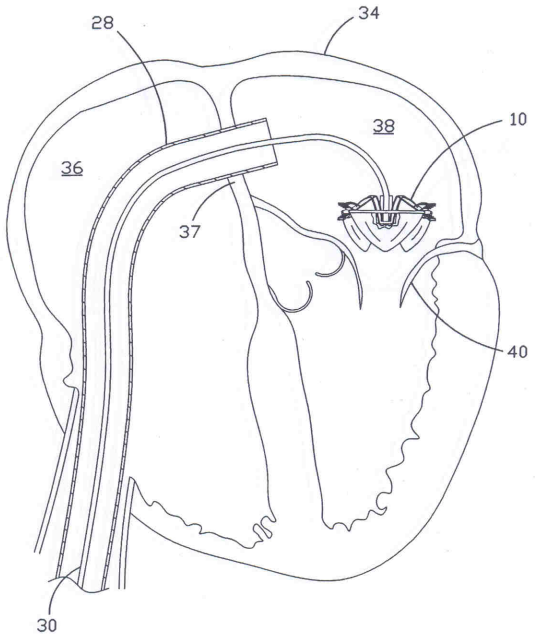
An artificial heart valve

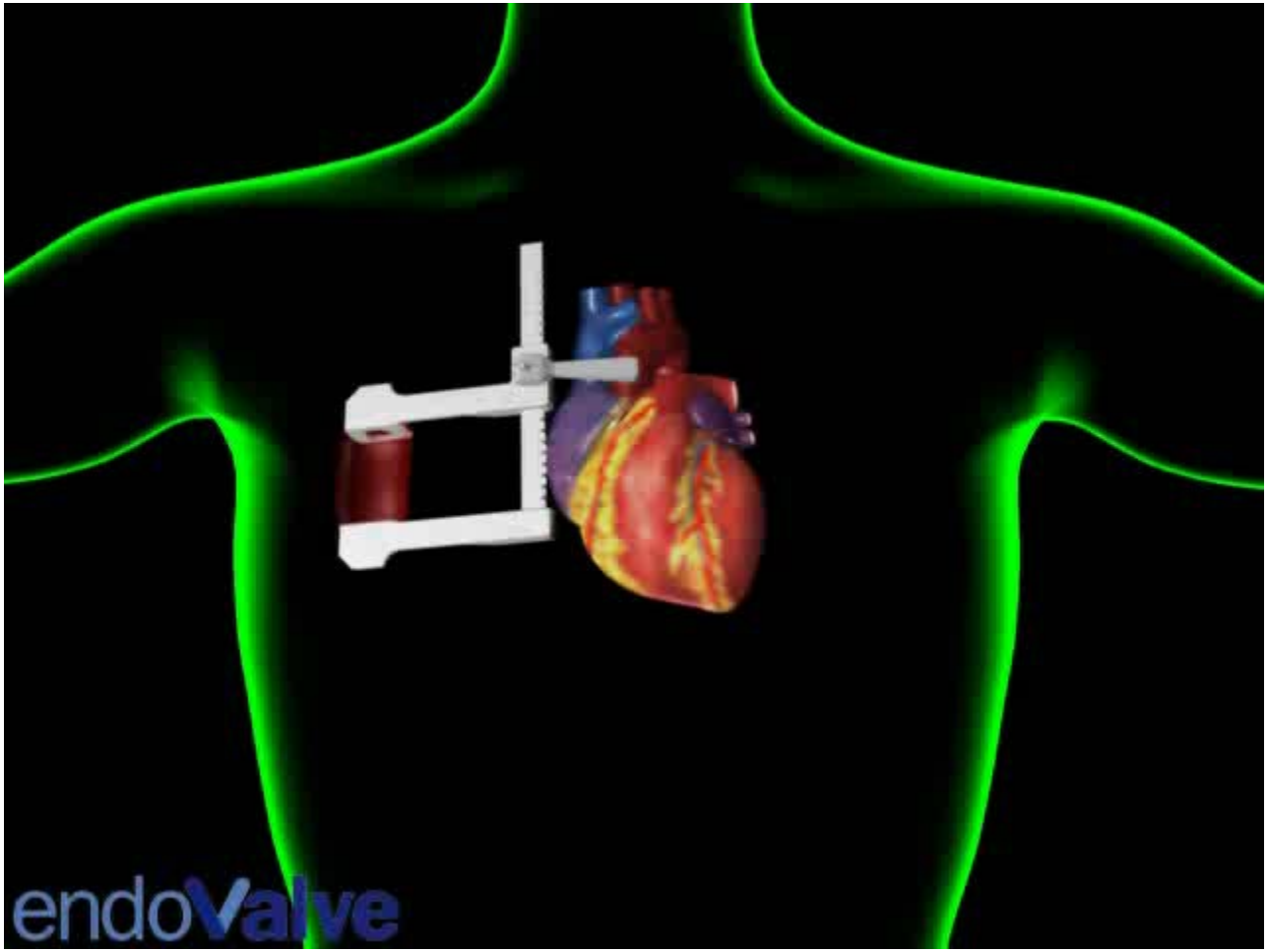




Currently under further development by Endovalve, Inc., USA

Patent

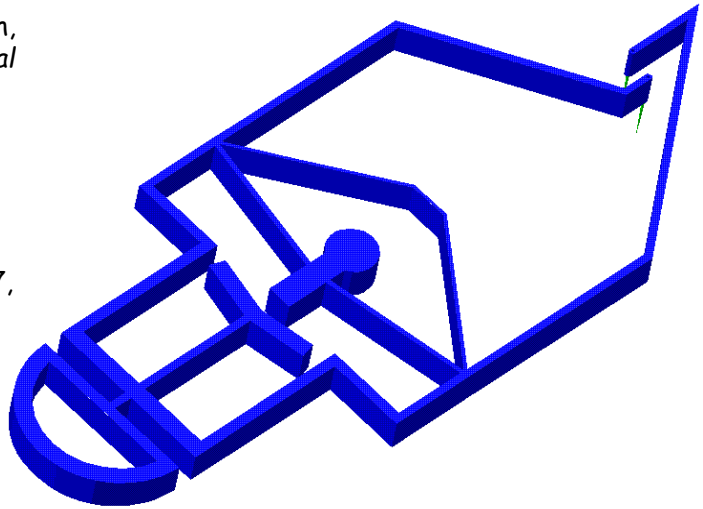
"Percutaneous Heart Valve," Patent application #. PCT/US2004/023211 dated 20th July, 2004 (H.C. Hermann and N. Mankame, G.K. Ananthasuresh)


endoValve

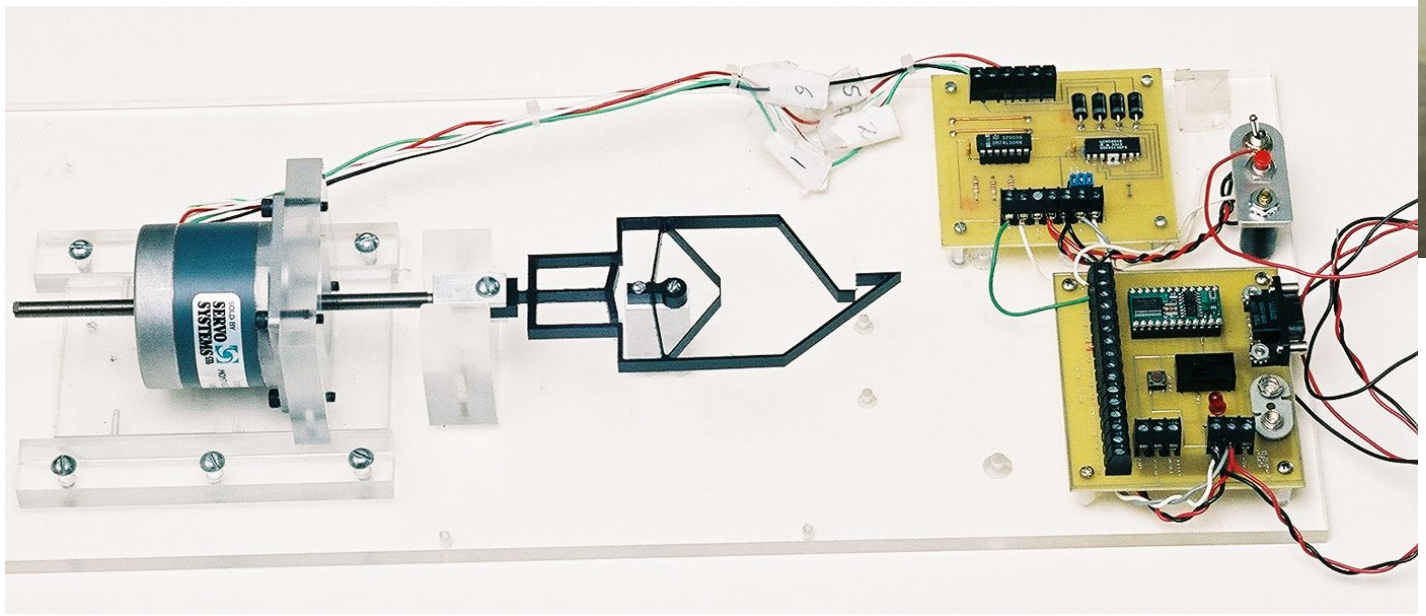
Non-smooth curved paths

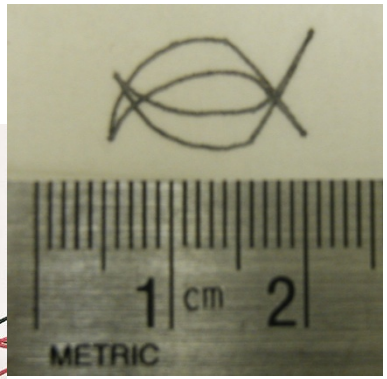
Mankame, N. and Ananthasuresh, G.K., *Journal of Mechanical Design*. 126(4), 2004, pp. 667-672.

Mankame, N. D. and Ananthasuresh, G. K., International Journal of Numerical Methods in Engineering, 69 (12), 2007, pp. 2564-2605.

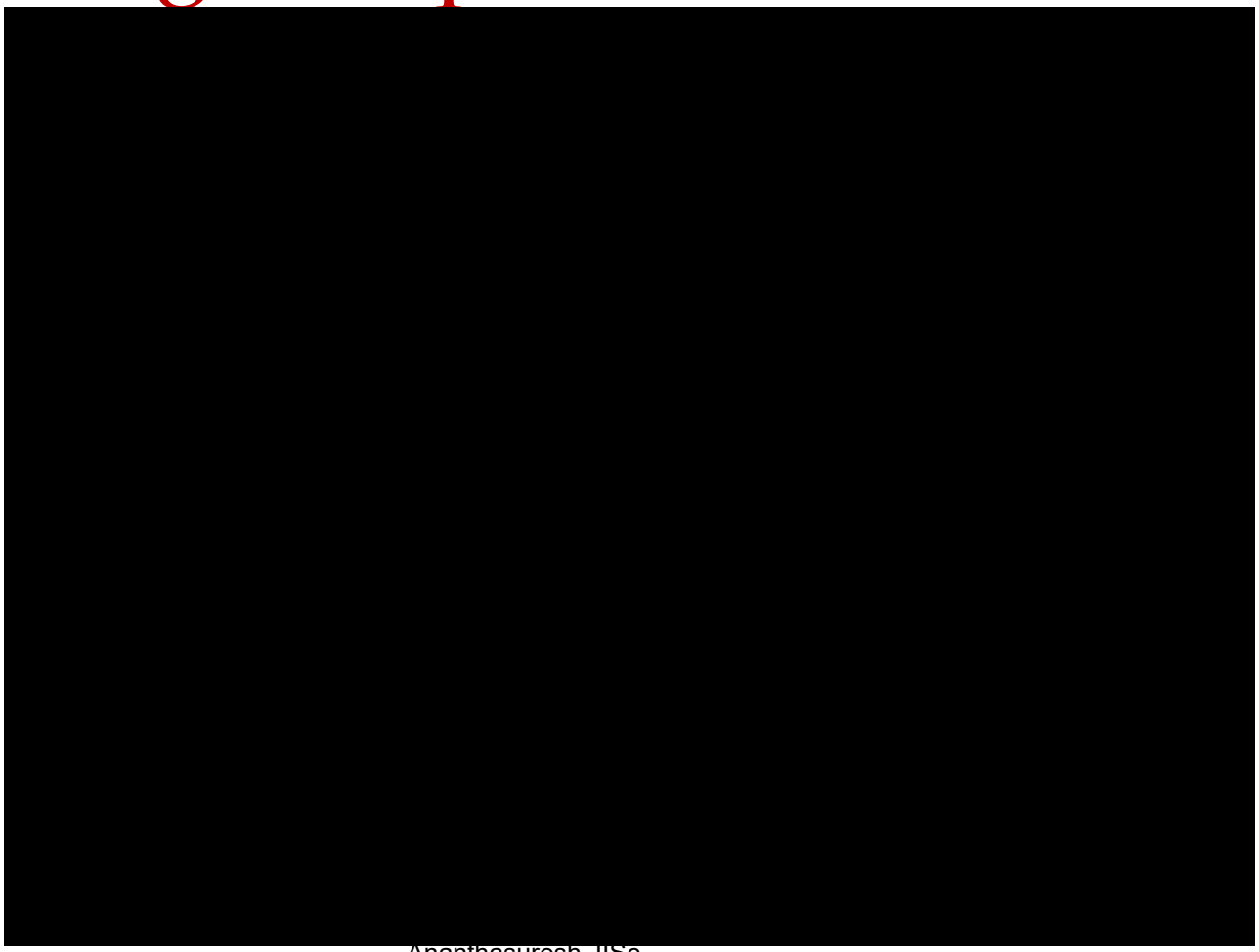


Movie





Non-smooth motion with smooth input using compliant mechanisms



Mechanical characterization of biological cells

Applications areas

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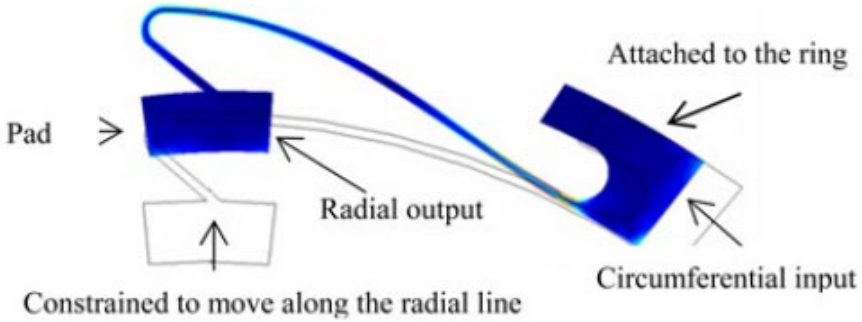
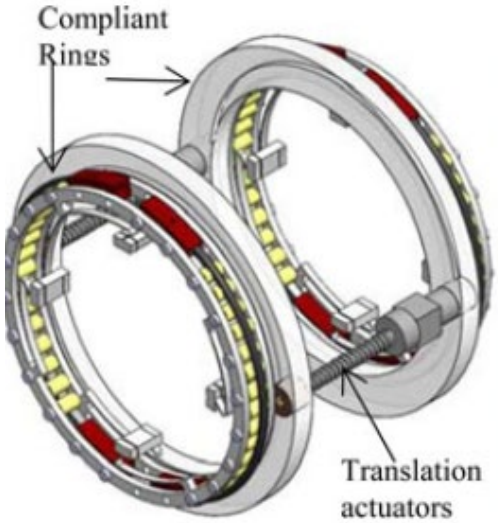
And more and more and more…

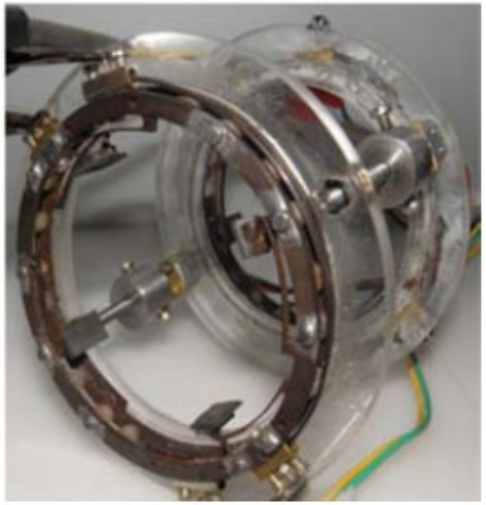
External pipe-crawler

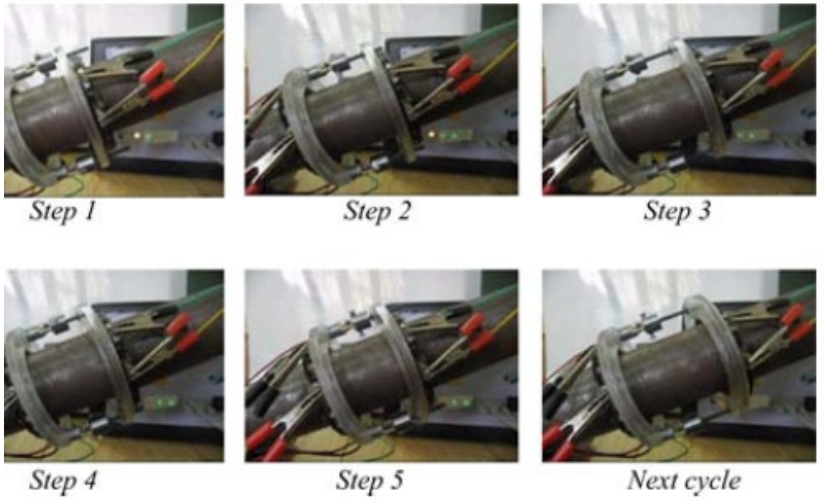
Inchworm concept

A compact ring-actuator





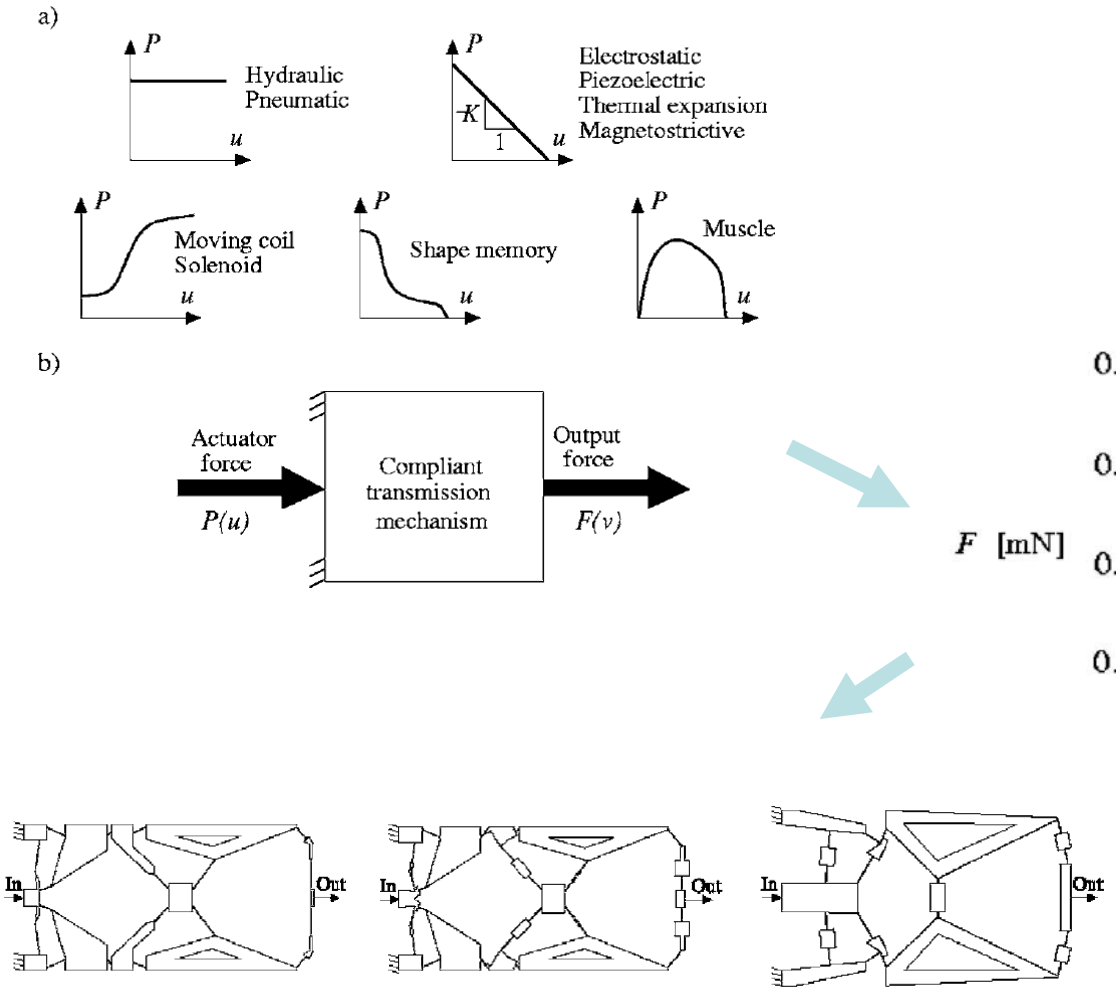




IEEE TRANSACTIONS ON ROBOTICS, VOL. 29, NO. 1, FEBRUARY 2013

With Puneet Singh et al.

Actuator characteristic modification



Pedersen, C. B. W., Fleck, N. A. and Ananthasuresh, G. K., *Journal of Mechanical Design*, 128(5), 2006, pp. 1101-1112.

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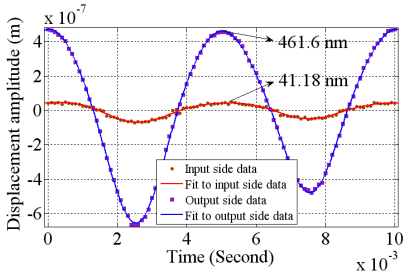
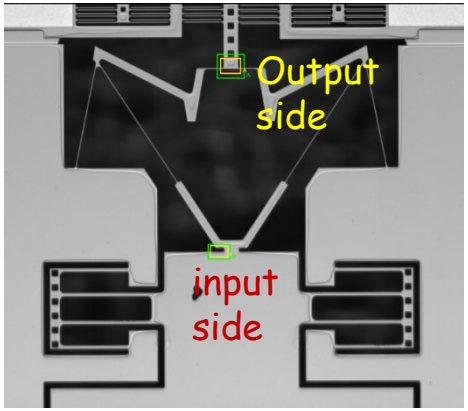
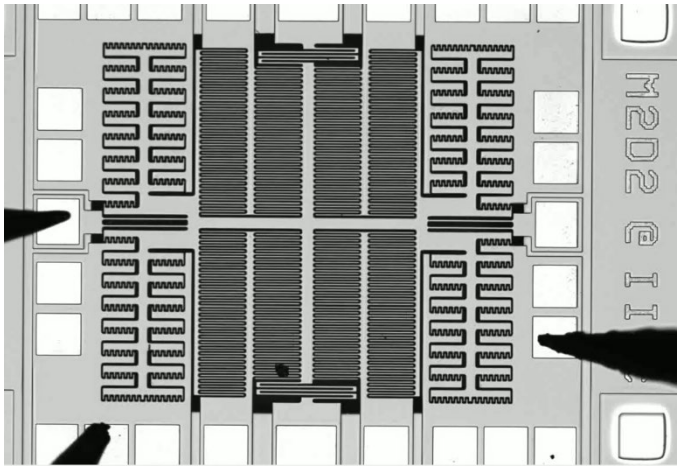
Micromechaical signal processors

- Band-pass filters
- Switches and relays
- Amplifiers
- Frequency-translators
- Clocks

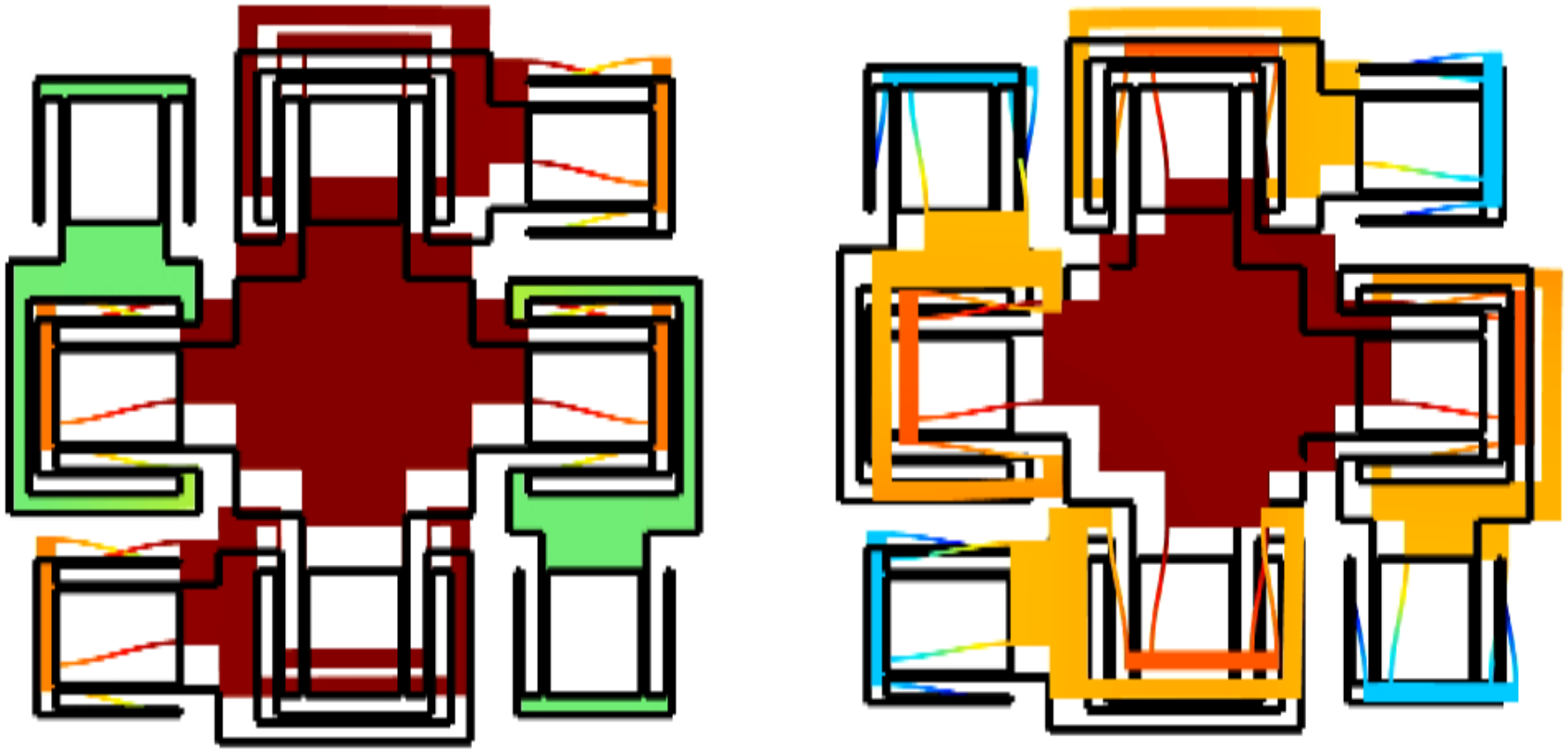




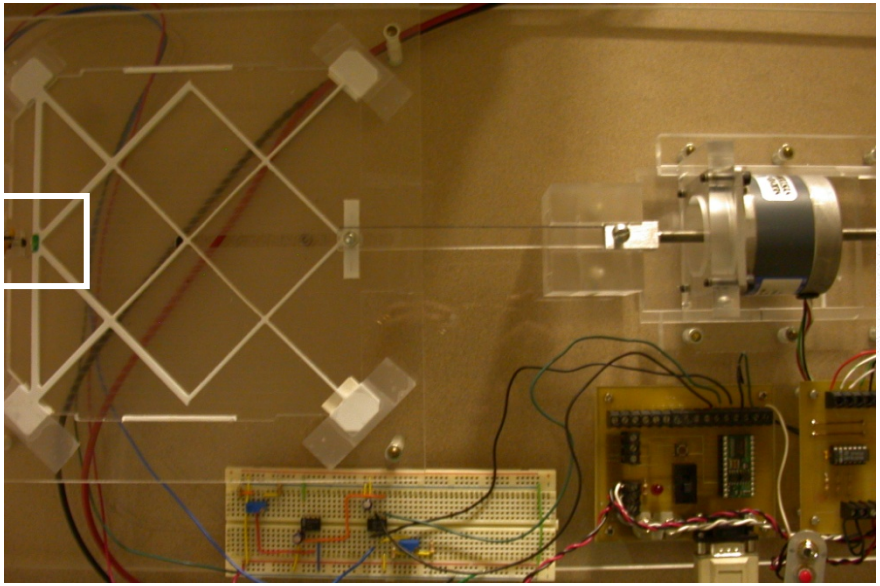


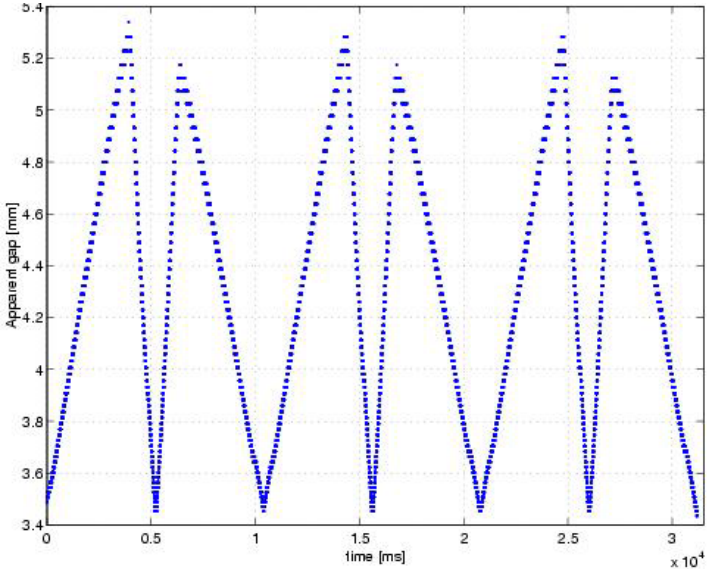
With Sambuddha Khan and Nirmit Dave

Separating x-y signals



A compliant cycle doubler





Mankame, N. and Ananthasuresh, G. K., "A Compliant Transmission Mechanism with Intermittent Contacts for Cycle-Doubling", *Journal of Mechanical Design*, 129(1), 2007, pp. 114-121.

Is compliant design difficult?

- Some people think so. It may be because…
  - you need to deal with elastic deformation.
  - you need to deal with elastic pairs and elastic segments as opposed to discrete rigid bodies.

- It is in fact easy once we pay attention to…
  - what benefits we can achieve with deformation
  - deformation mechanics in addition to kinematics

Models for analysis

- Empirical modeling of elastic pairs
- Elastica analysis of beam segments
- Pseudo Rigid-Body (PRB) modeling
- **Finite element analysis**
- Spring-Lever (SL) and Spring-Mass-Lever (SML) modeling
- Compliant ellipsoid modeling
- Non-dimensional maps

Synthesis methods

- Kinetostatic synthesis using PRB modeling
- **Topology and shape optimization**
- Selection and re-design
- Instant-centre method
- Design using building blocks
- Pragmatic design with non-dimensional maps
- Intuitive design using a kit