VARYING SPRING PRELOADS TO SELECT GRASP STRATEGIES IN AN ADAPTIVE HAND

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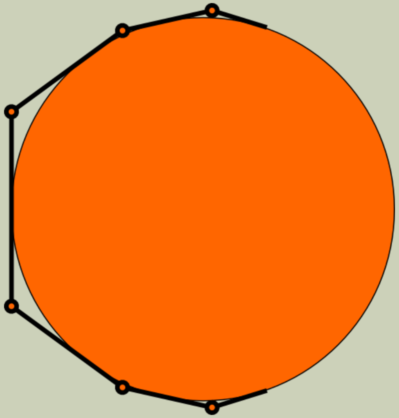
PROJECT BACKGROUND

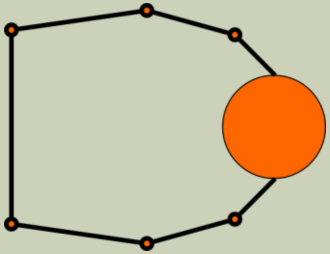
- Autonomous undersea drilling platform
  - Remote, inaccessible
- Two robot arms with interchangeable end-effector
  - Tools for repeated operations
- Hand that accommodates many shapes and sizes
  - Able to pick up heavy objects
  - Won’t damage light objects

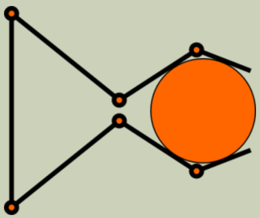
seabed RIG

GRASP STRATEGIES

- Wrap grasp
  - Large objects
  - Secure grasp, many points of contact
- Pinch grasp
  - Small objects
  - Relies on friction
  - Dexterous
  - Requires full actuation
- “Power-pinch” grasp
  - Grasp small objects securely
  - Don’t care about dexterity
  - Doesn’t require full actuation

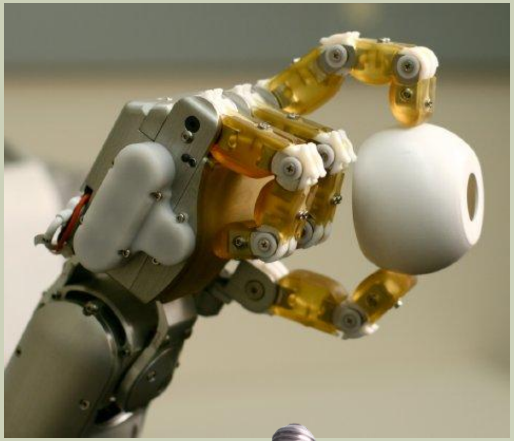


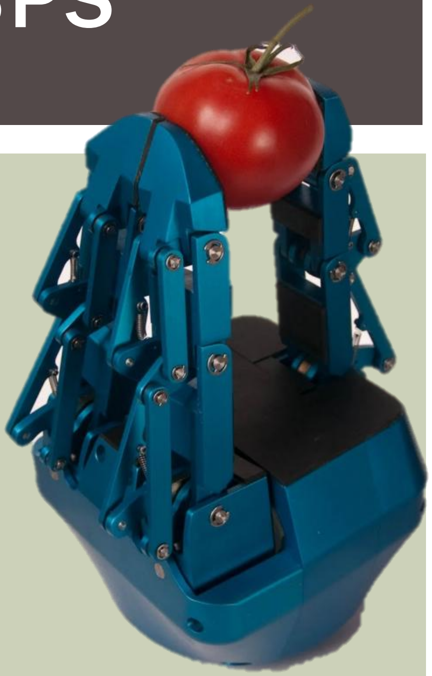


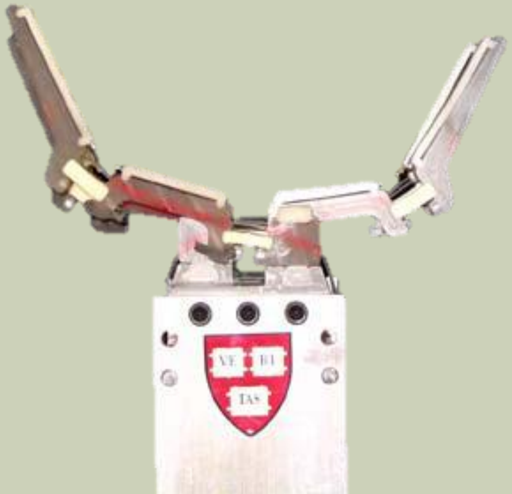


MOTIVATION – PINCH GRASPS

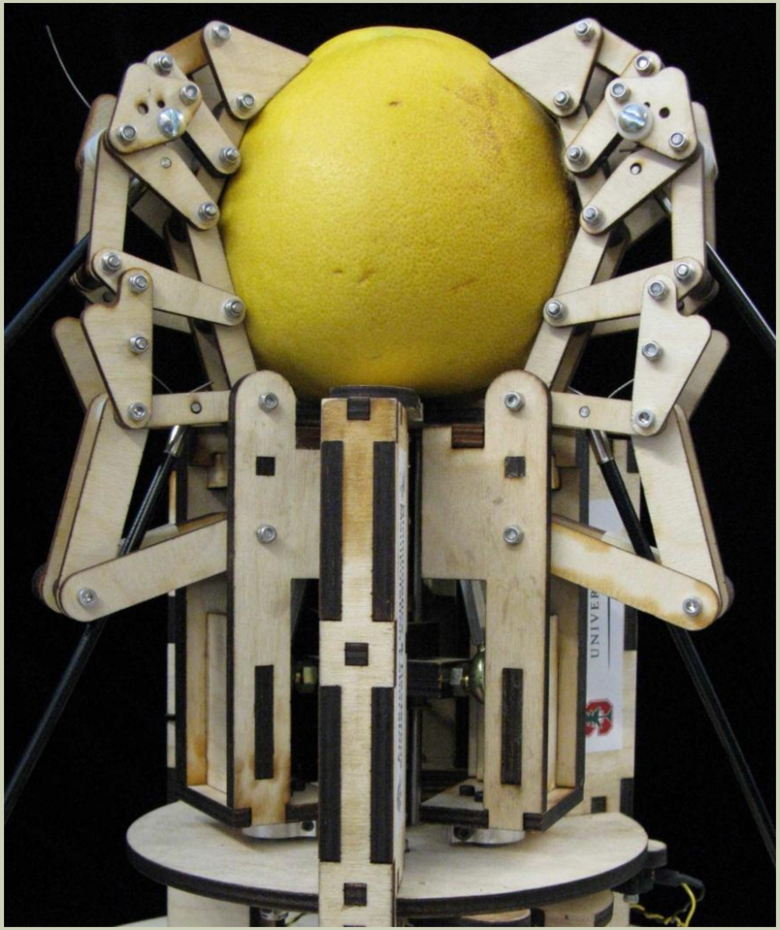
- Hands generally pinch smaller objects with fingertips
  - Few contacts
  - Point or line contacts
  - Requires soft pads to improve contact
- Underactuated hands cannot fully control finger configuration
  - SDM Hand, Meka Hand rely on kinematics & springs
- Robotiq adaptive gripper keeps fingertips parallel
  - Less reliance on friction

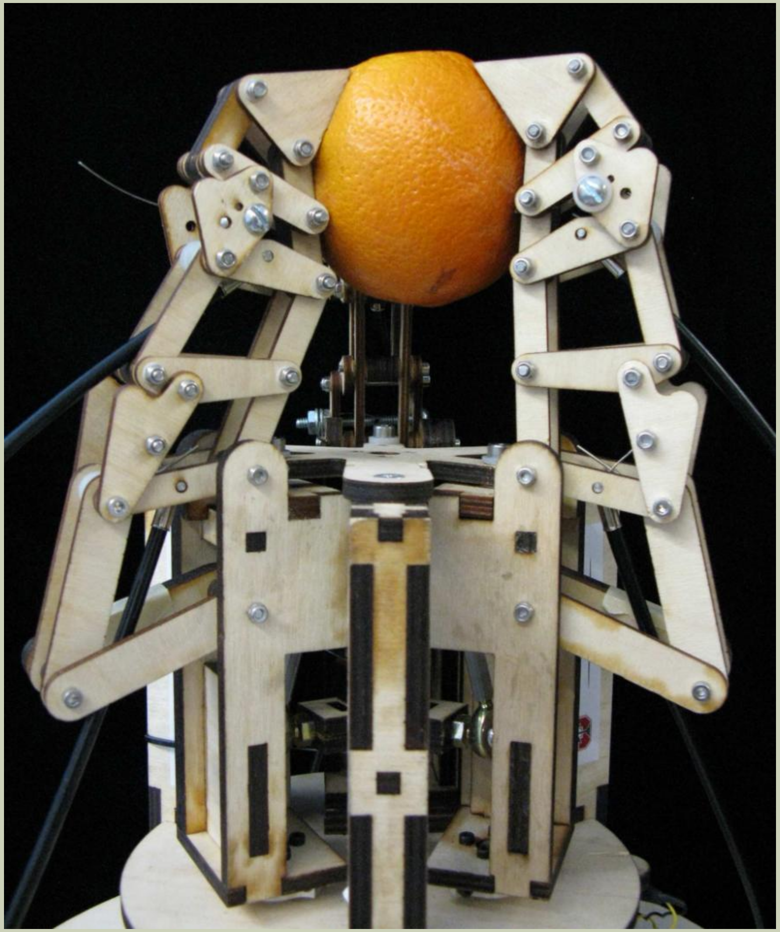




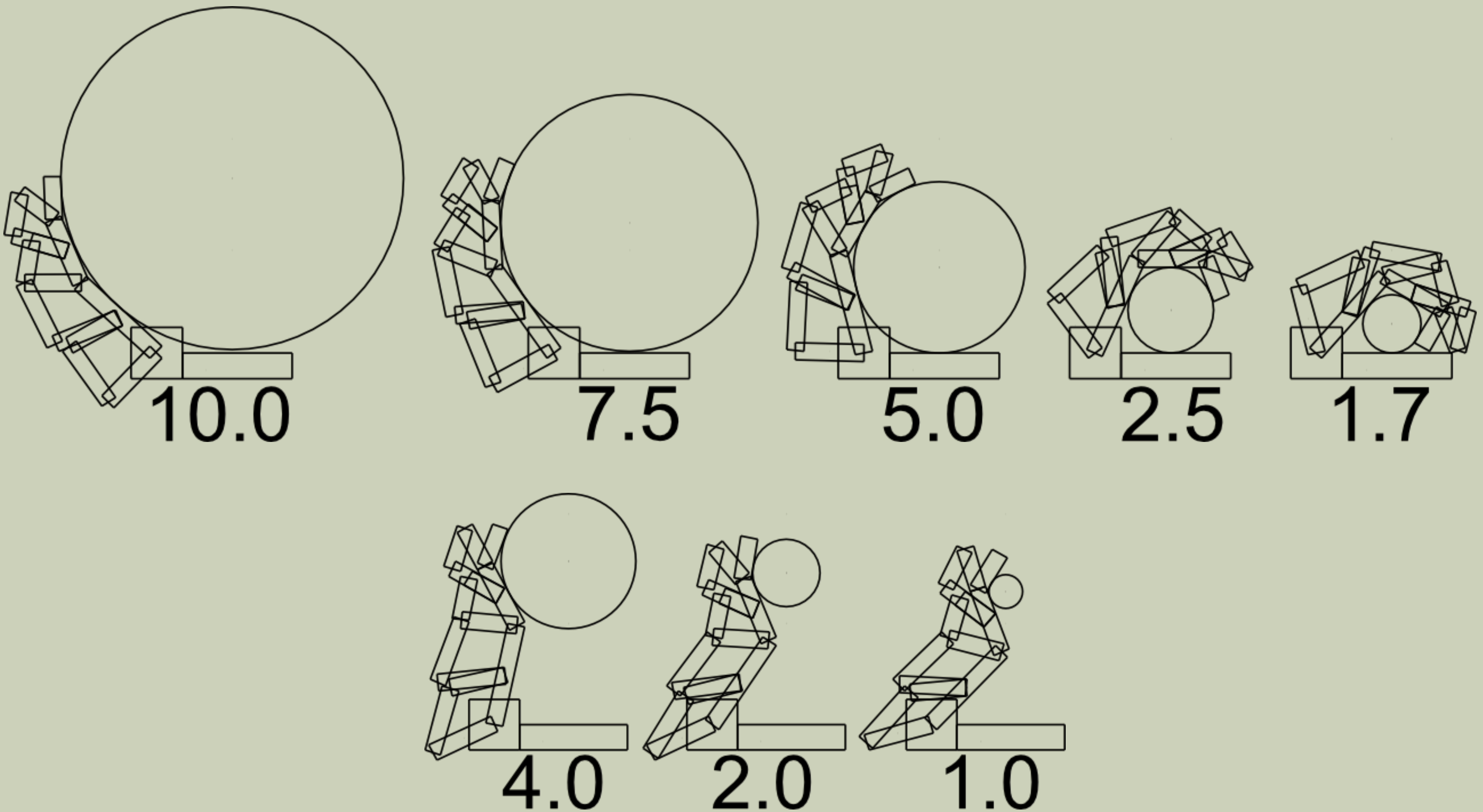


SEABED HAND

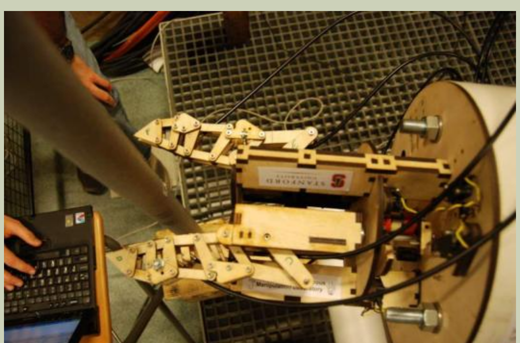


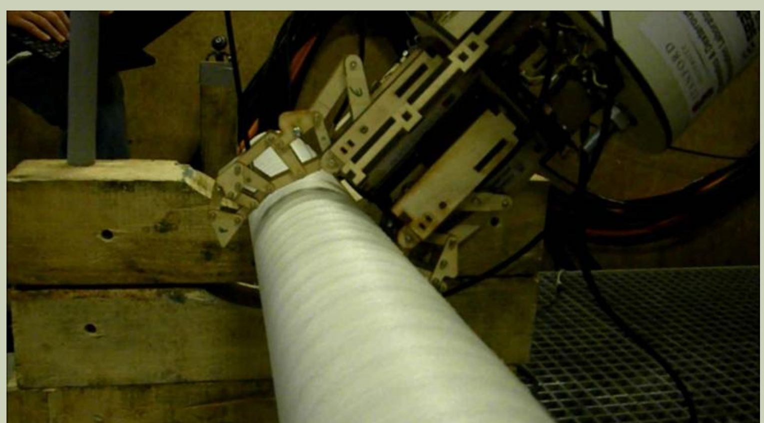


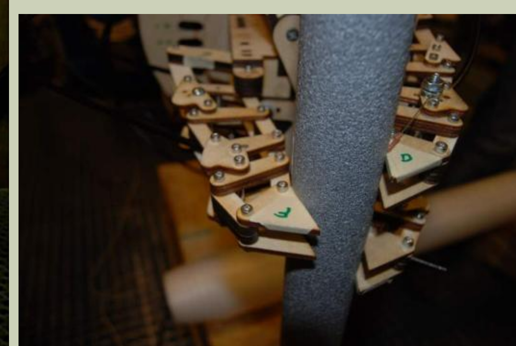
RANGE OF GRASPABLE OBJECTS



THE HAND IN ACTION

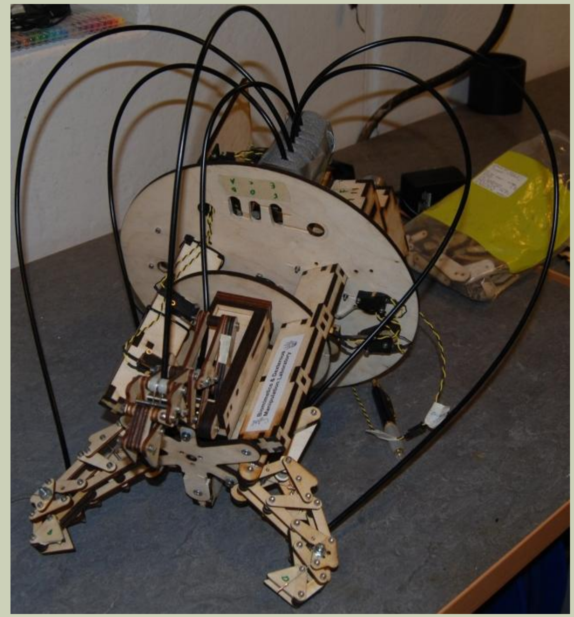


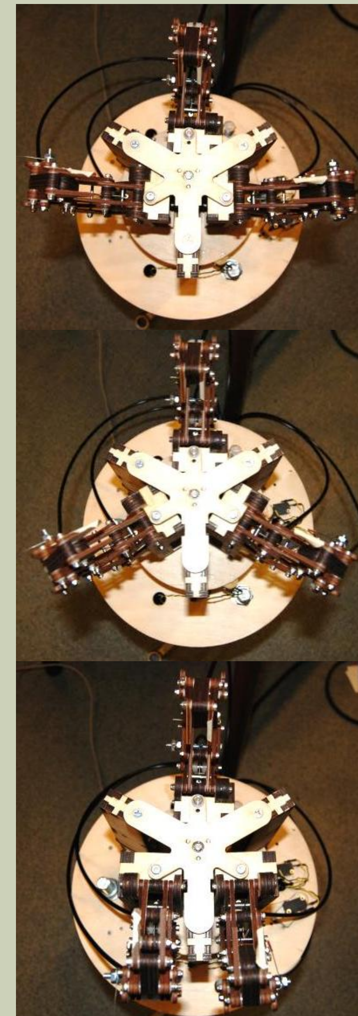




BASIC DESIGN

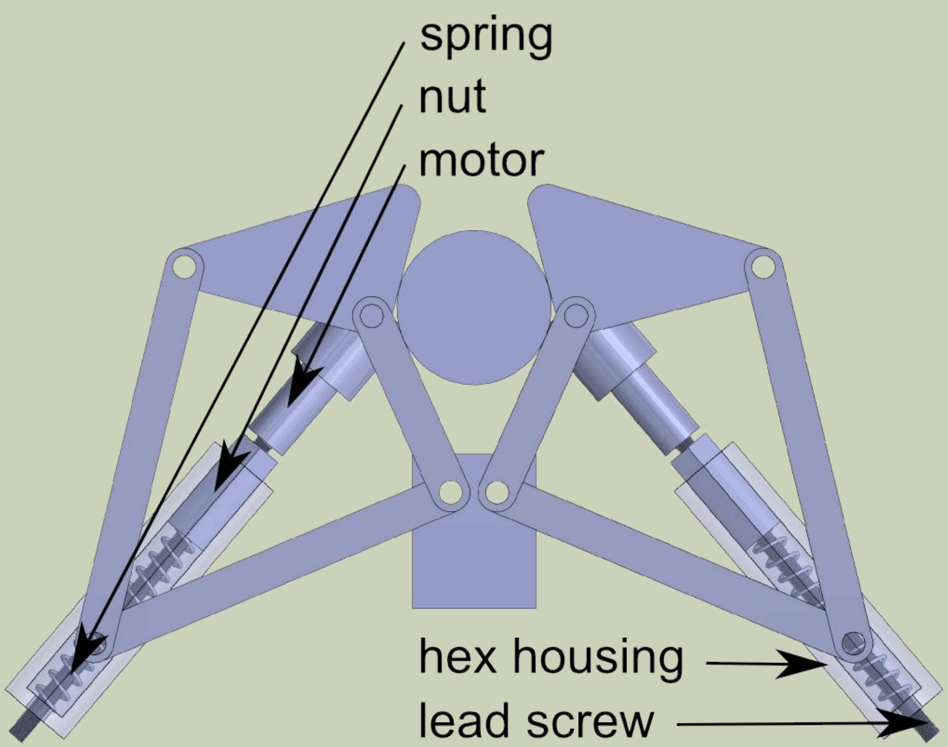
- 3 Motors
  - Open / Close Fingers
    - Located in the base
    - Drives a leadscrew
  - Reconfigure Fingers
    - Located in the base
    - Rotates two motors 90 degrees
  - Stiffen the fingers
    - Cable drive located in base
    - Pulley differential stiffens the finger
- Issues
  - High-friction
  - Complicated





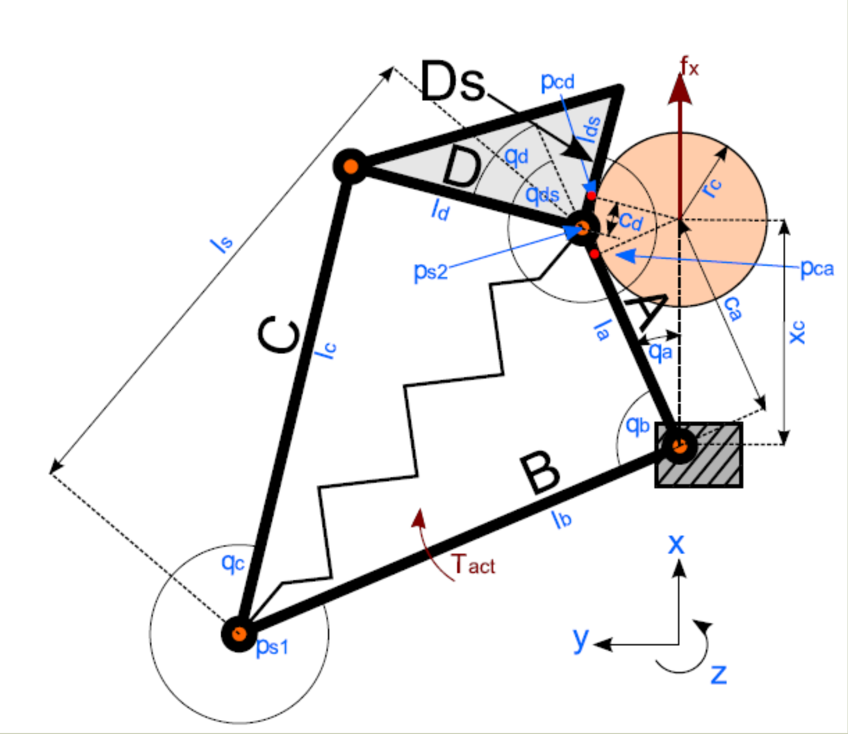
SPRING PRELOAD MECHANISM

- Adaptive mechanism
  - Lowers sensing and control requirements
  - Protects the motor and transmission from shock and vibration
- Actuators
  - Small, low-power, non-backdriveable
  - Located in the finger
  - Simpler design



VARIABLES AND EQUATIONS

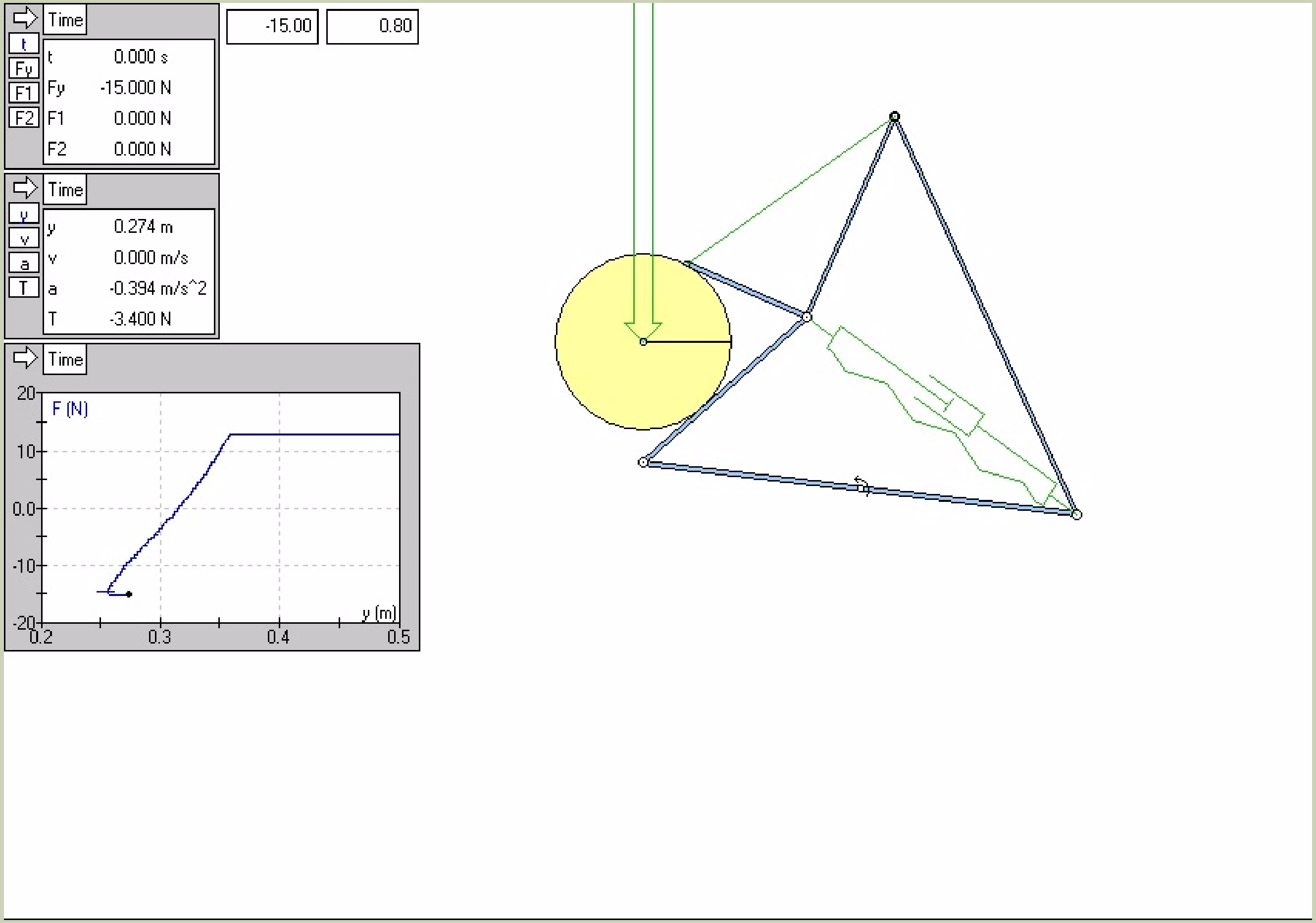
$$\left(\mathbf{J}_{act}^{T}\tau_{act} + \mathbf{J}_{cn}^{T}\mathbf{f}_{cn} - \mathbf{J}_{s}^{T}f_{s}\right)\dot{\mathbf{q}}_{ind} = 0,$$



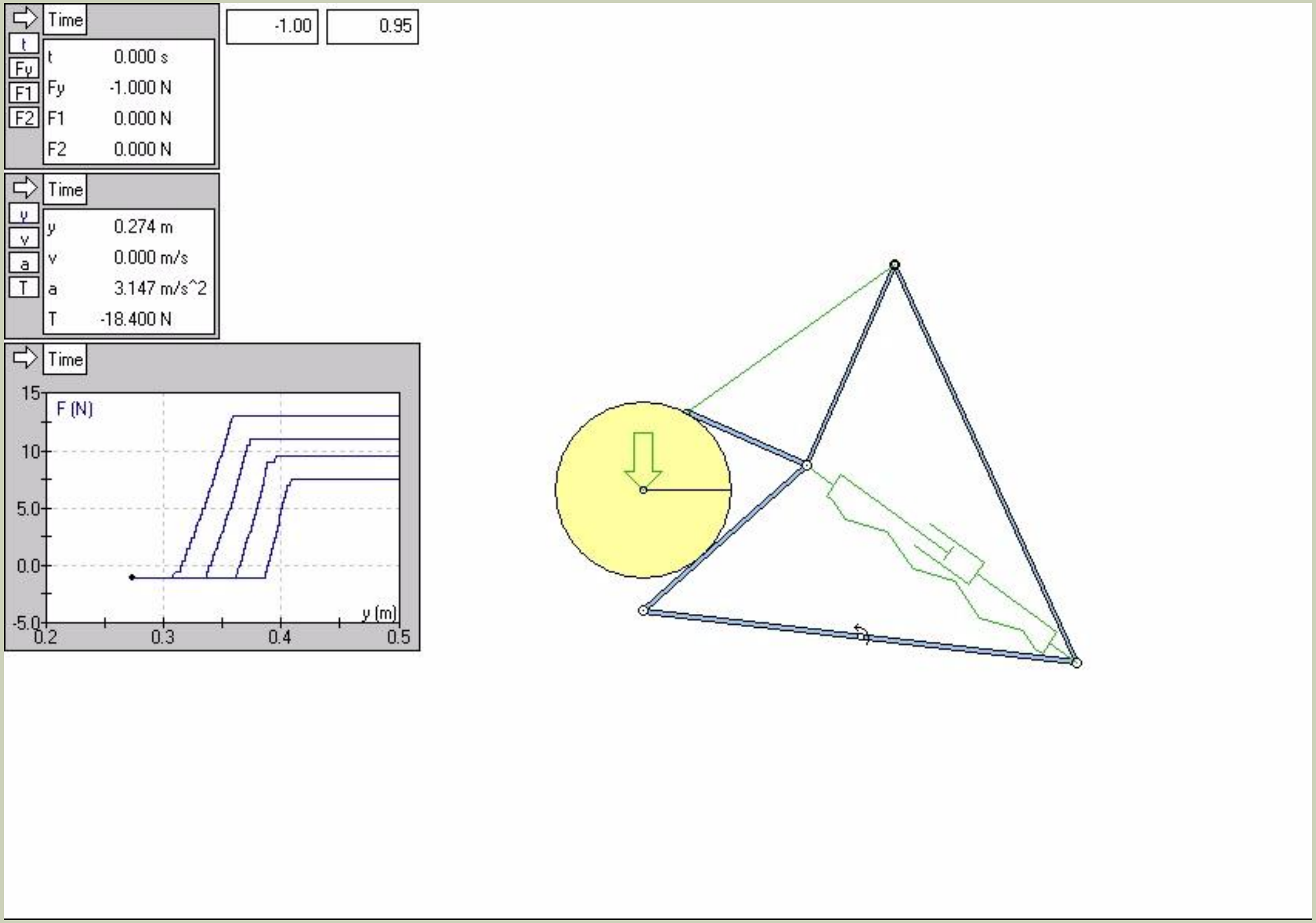
Assumptions:

- Frictionless
- Circular object
  - Contact points are only a function of position.
- Symmetric
- Two-phalanx contact
- Finger position is a function of xc.

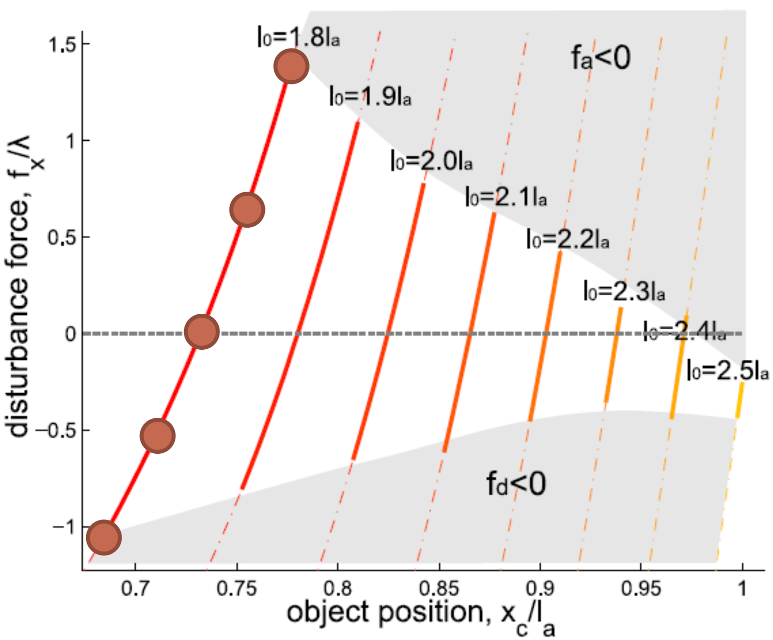
SMALL SPRING PRELOAD



MEDIUM SPRING PRELOAD



WAYS TO UNDERSTAND GRASPING



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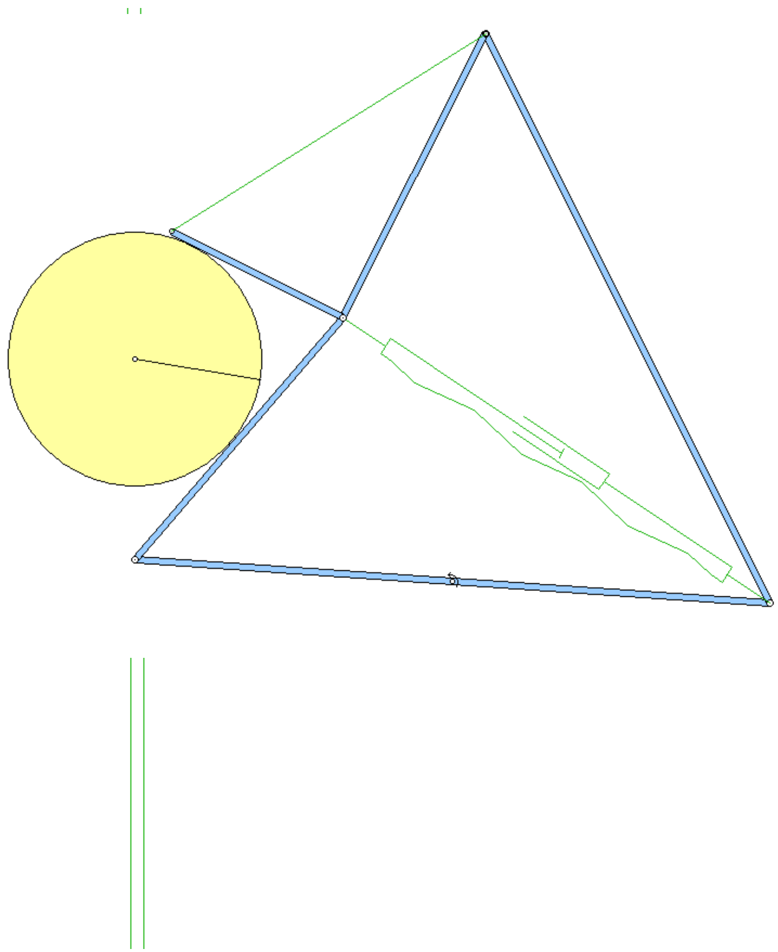
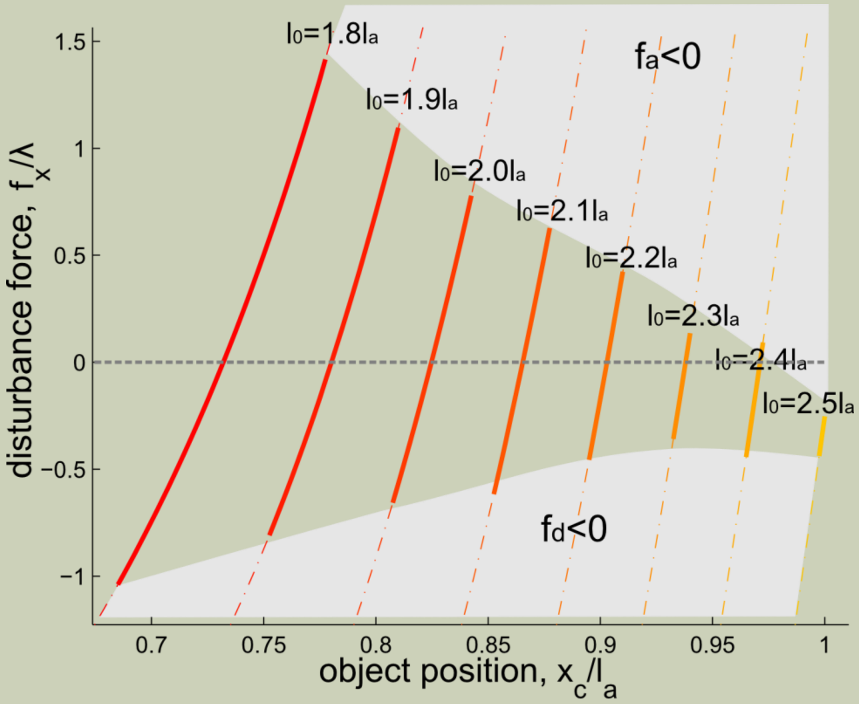


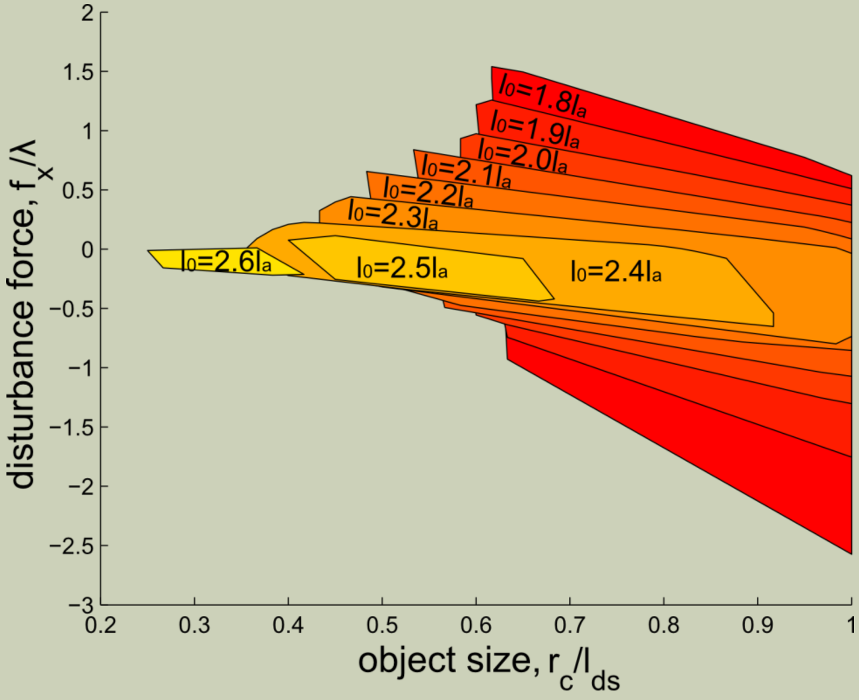
STIFFNESS INTERPRETATION

- Effective stiffness
  - $k_{effective} = \frac{\partial F}{\partial x}$
- Lower preloads
  - Lower grasp stiffness
  - Higher range of perturbations
- Higher preloads
  - Higher effective stiffness – more precise
  - Lower range of perturbations



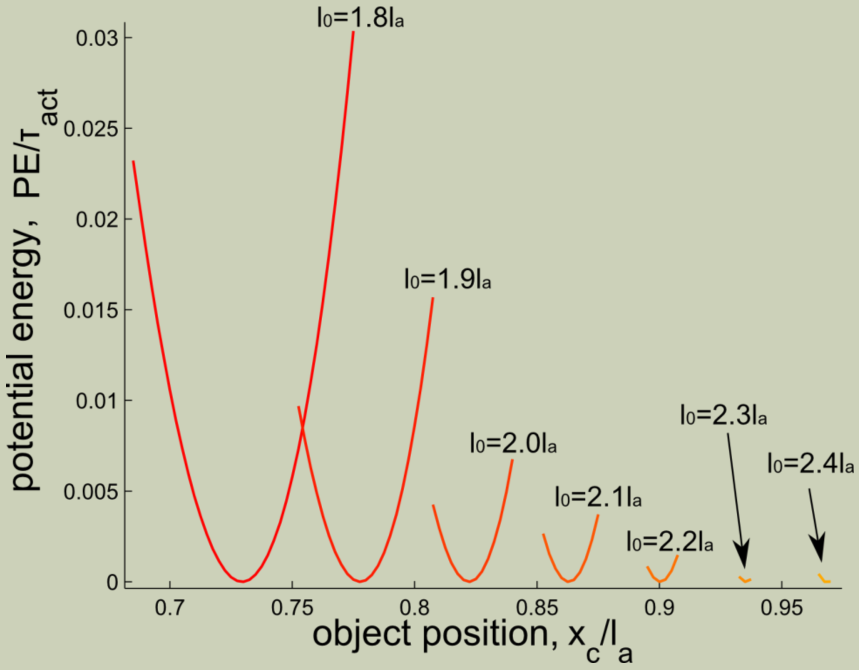
RANGE OF OBJECTS WHICH CAN BE GRASPED

- No single preload can grasp all objects
- Tradeoff between versatility and optimality
- Fingertip interference considered



POTENTIAL ENERGY

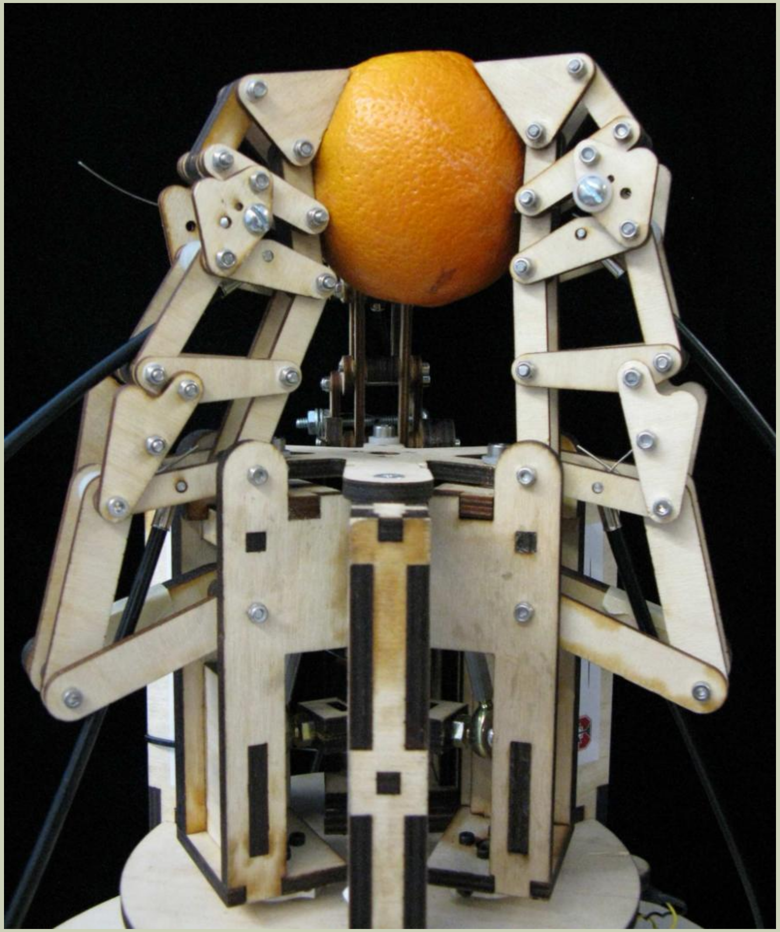
- Integrate pulling forces over the distance traveled
- Minimum Potential energy when f=0
- Potential Grasp Metric
  - Useful for design
  - Symmetric curves are good



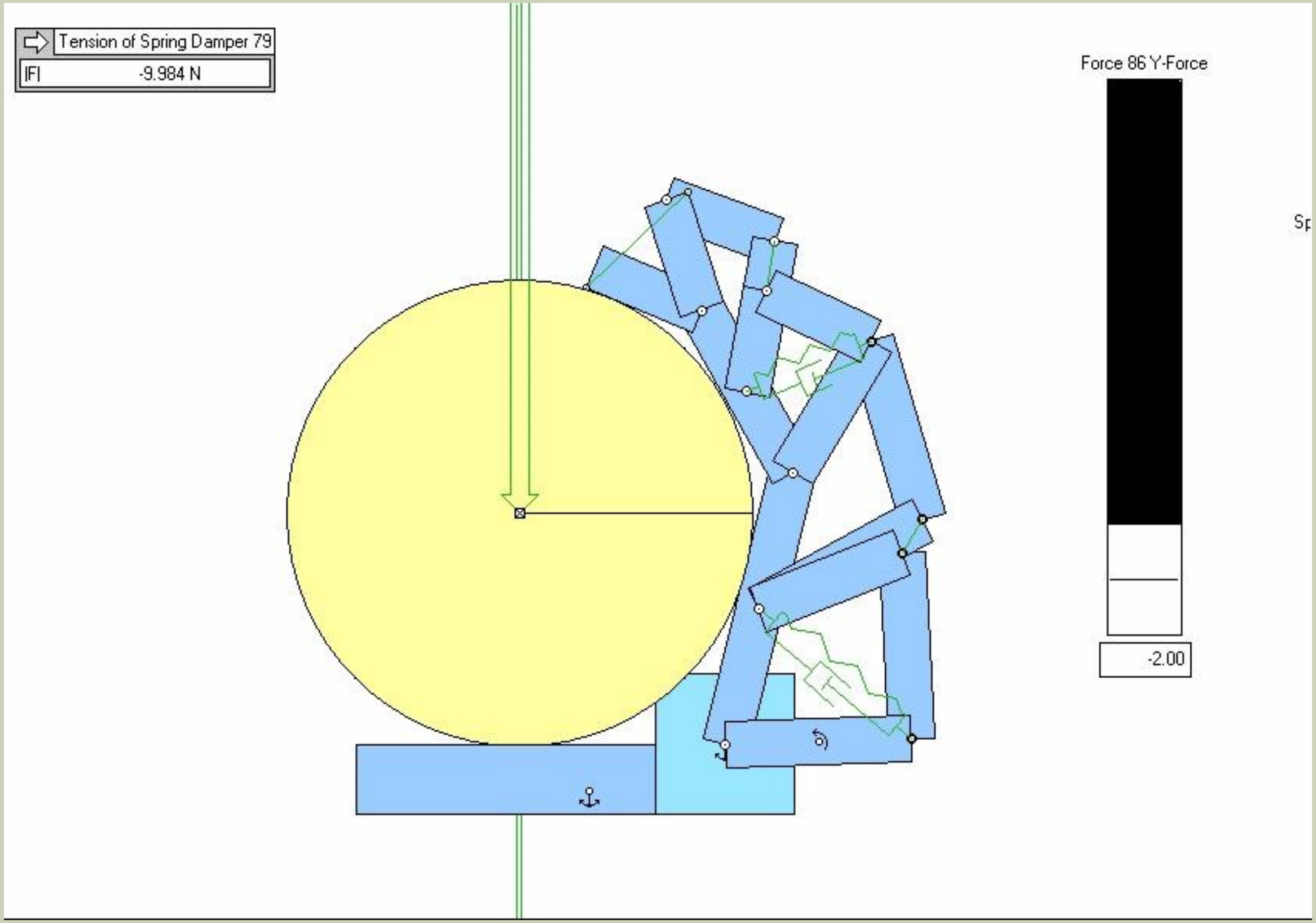
SEABED HAND ANALYSIS

- Three-phalanx
- Start in stable grasp
- Quasi-static
  - Let velocity go to zero
  - No contact friction, but spring is damped
- Four Cases:

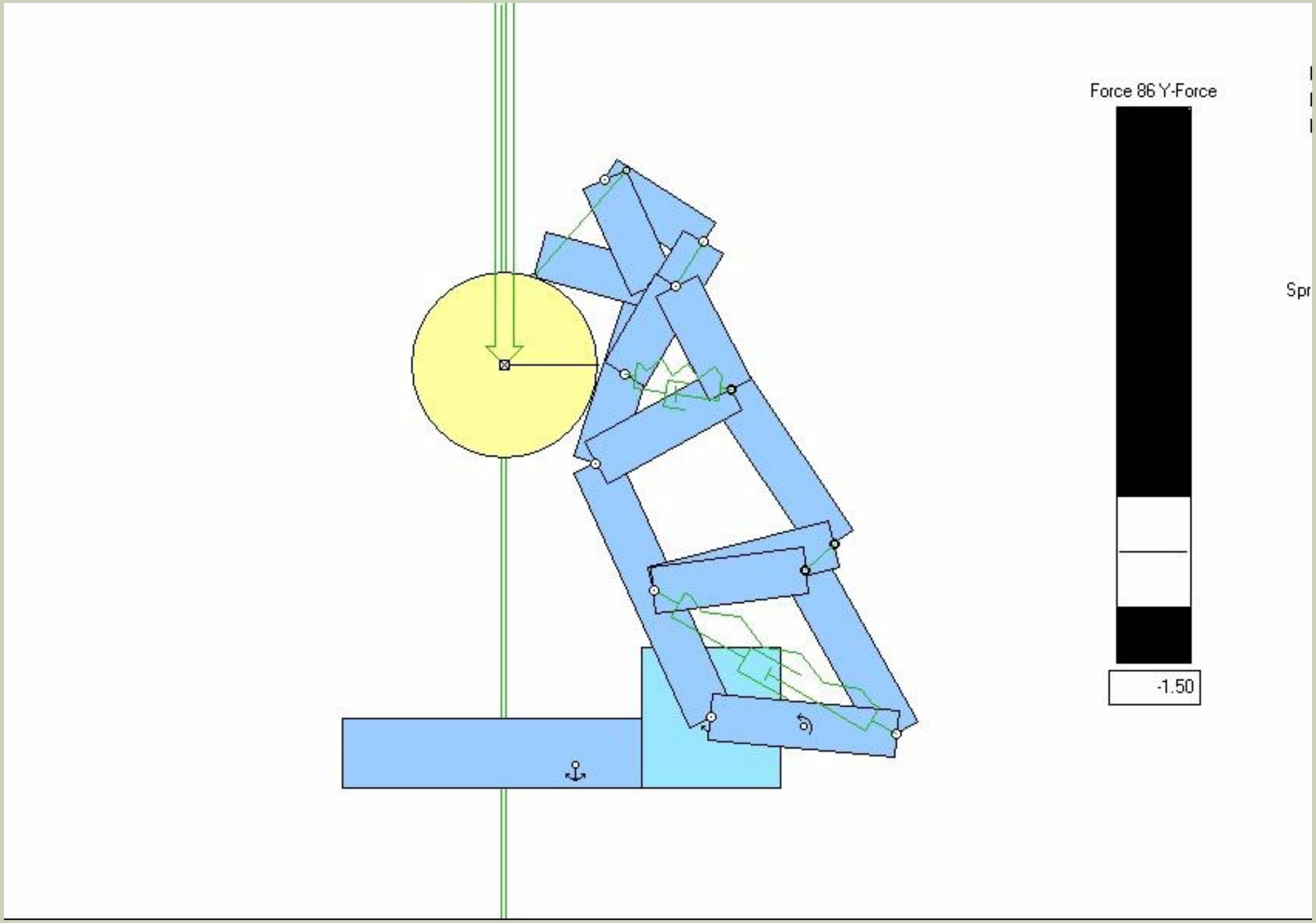
Case	r_c	$l1_0$	$l2_0$
1	50mm	68mm	28mm
2	20mm	95mm	35mm
3	20mm	68mm	28mm
4	50mm	95mm	35mm



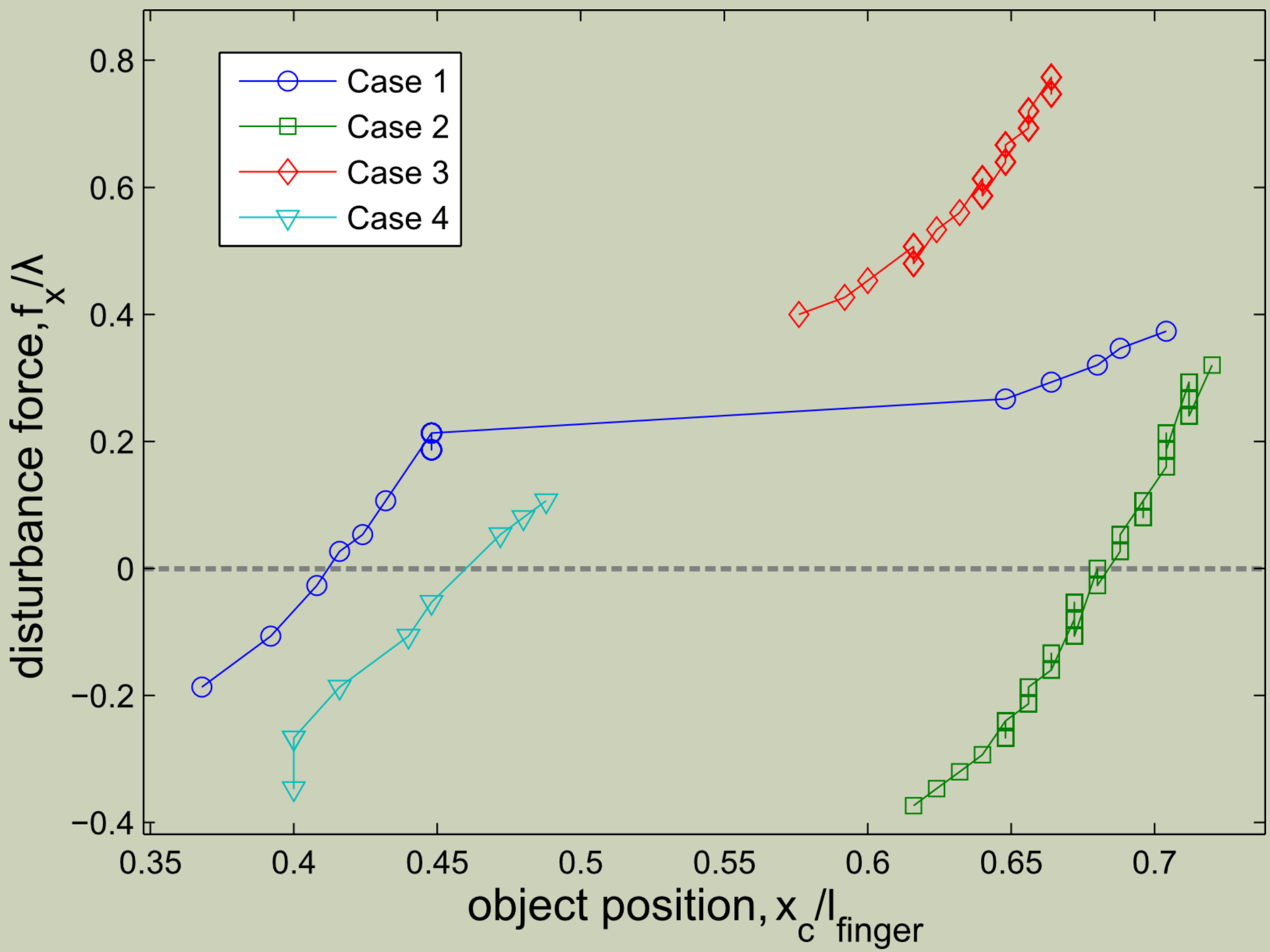
WORKING MODEL SIMULATION



GRASPING A SMALL OBJECT



FORCES IN SEABED HAND



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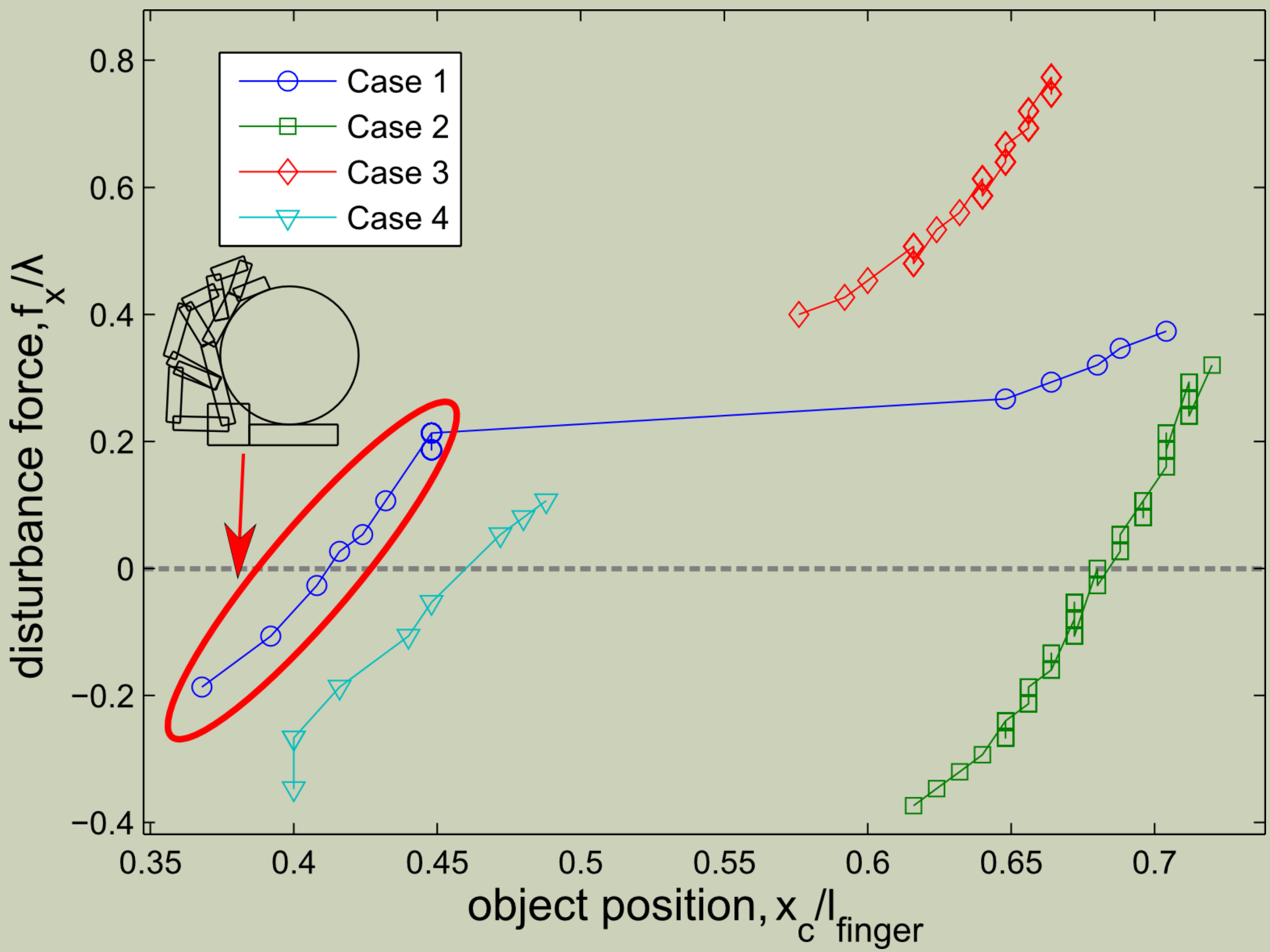

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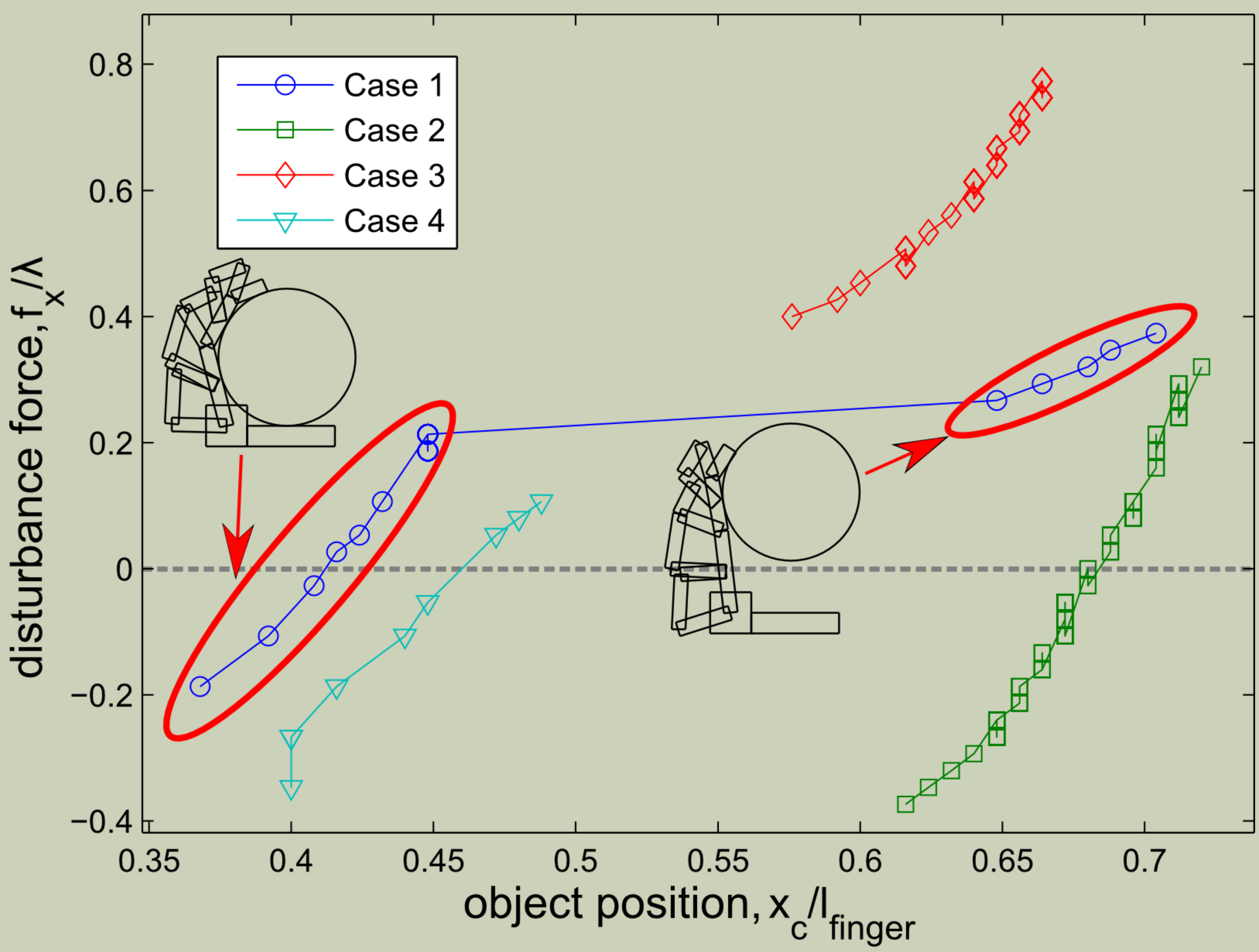

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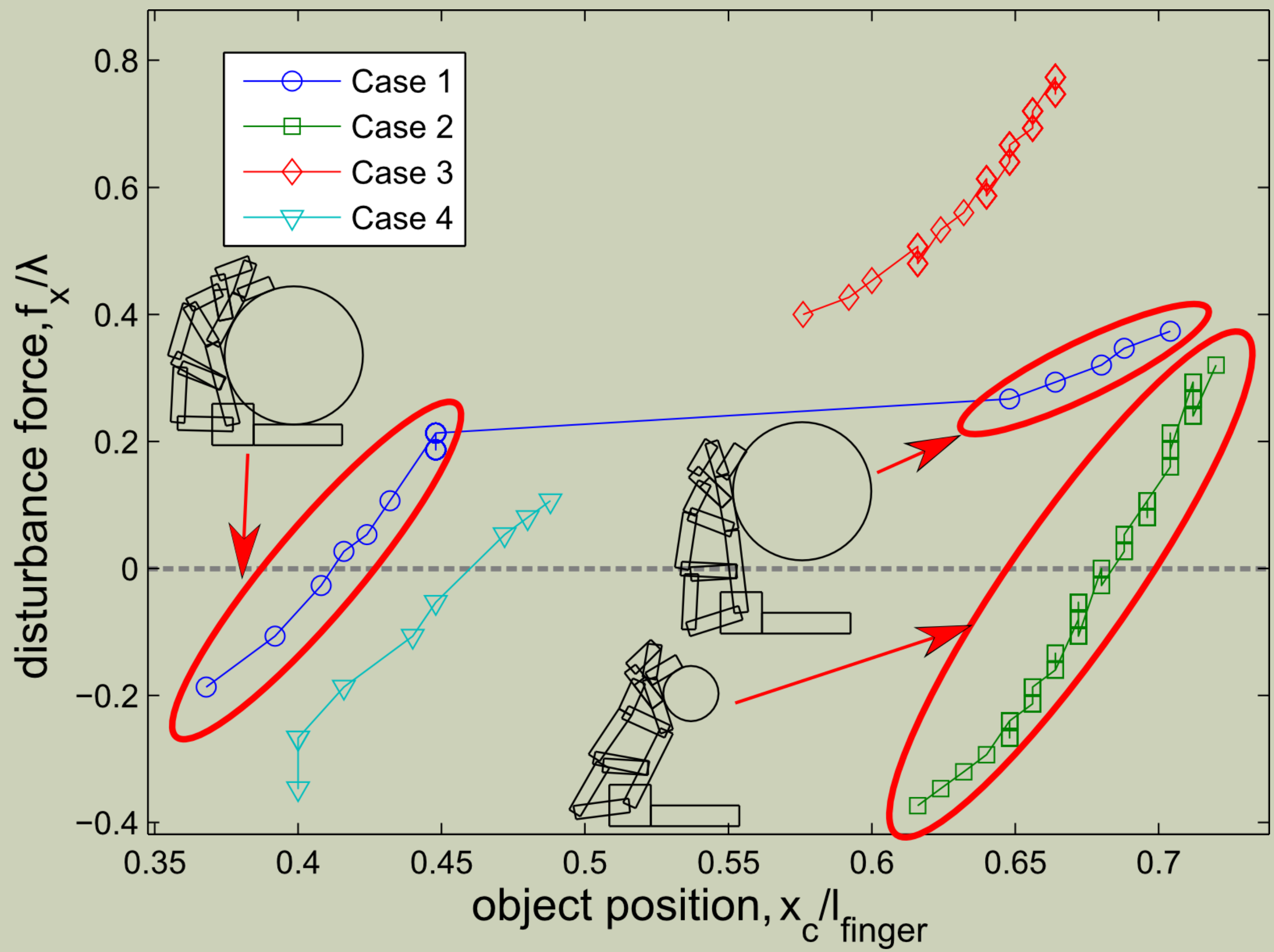
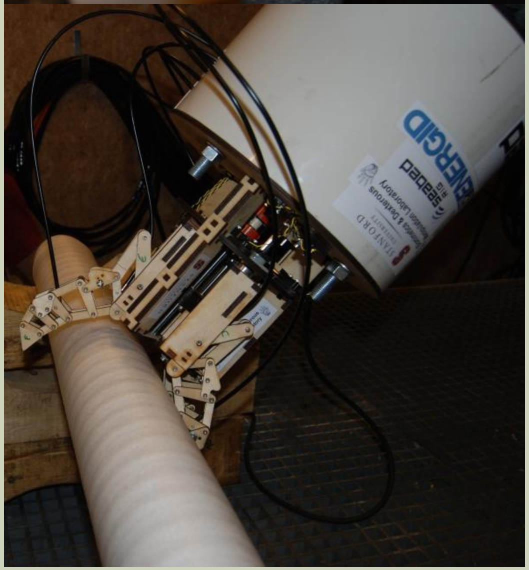


DISCUSSION

- Trade-off
  - Object size
  - Posture
  - Effective grasp stiffness
  - Disturbance force rejection
  - Energy absorption
- Example Tasks
  - Impacts:
    Small preload → Low grasp stiffness
  - Precision:
    High preload → High grasp stiffness
  - Slow-speed manipulation



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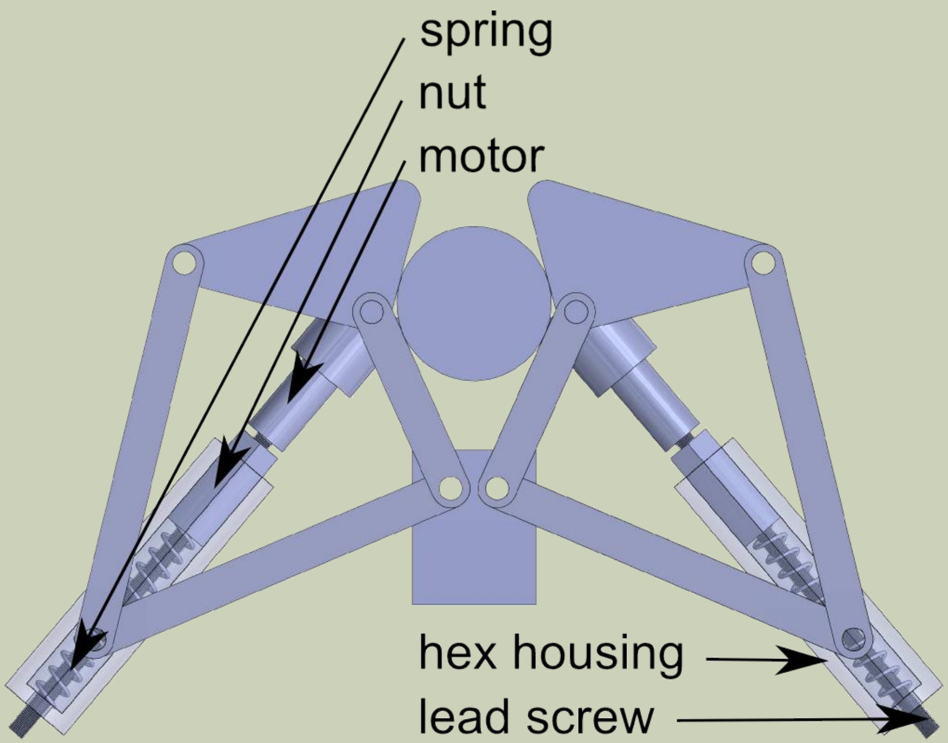

CONCLUSIONS

- Introduced the "power-pinch"
- Wider Range of Objects – 10:1
- Improved Grasp Stability
- Next Steps
  - Optimize kinematics.
  - Use grasp metrics as a design tool.
  - Develop new control strategies for spring preload mechanism

THANKS

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