Investigating the Use of Shape Memory Polymers for Application in Modular Robotics

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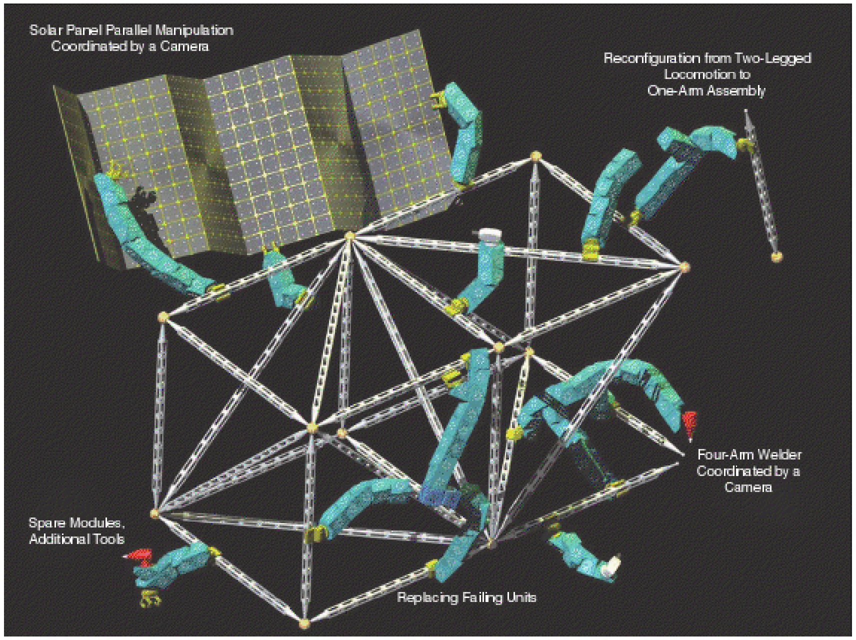
Modular Robots

- Each module has all components of a functioning robot.
- Modules are able to:
  - Communicate
  - Move
  - Connect and Disconnect
- The robot is reconfigurable

Various configurations of CK bot module from Dr. Yim's Modlab

Advantages of Modular Robots

- Versatility
  - Space Exploration
- Robustness
- Low Cost



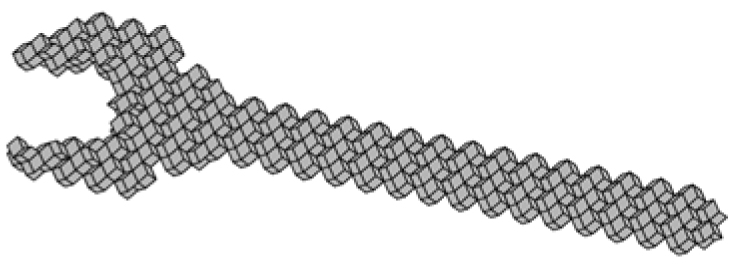
Yim et al. IEEE, 2007

Challenges in Modular Robotics

- Low cost modules have not been realized
- Mass production is not yet been used.
  - Control algorithms could handle millions of modules
  - Currently, modular robot with the most active modules, 56, is Polybot, created by Yim et. al.

Challenges In Modular Robotics

- Scalability
  - Smallest module is Miniature, created by Yoshida et. al. with dimensions 40mm x 40 mm x 50mm

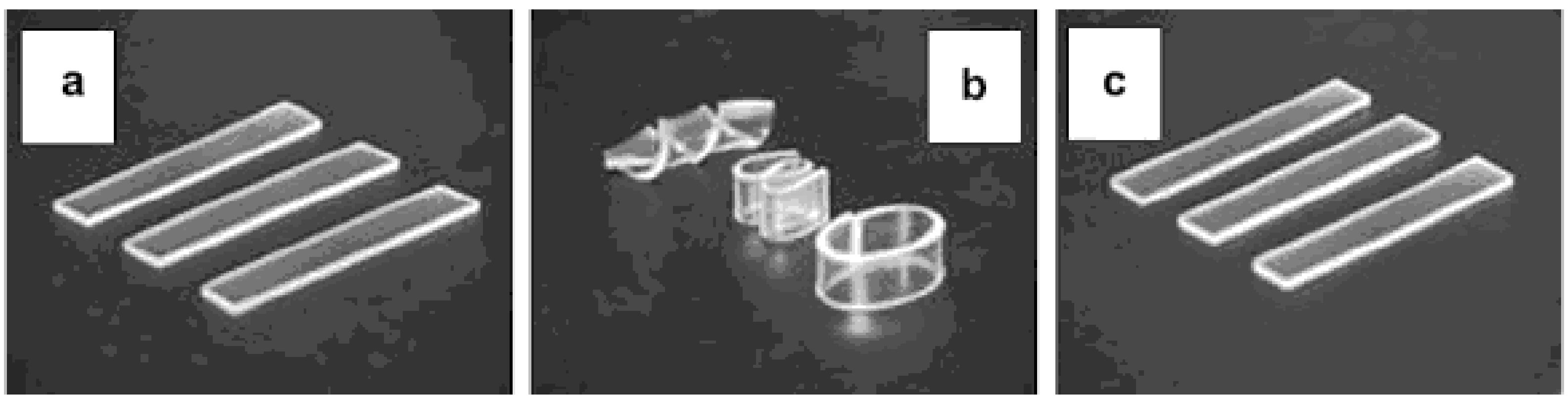


Actuators

- Allow modules to move
- Brushless DC motors usually used.
- Contribute much of weight and volume of modules.

Shape Memory Polymers (SMP)

- Memorize a temporary shape and then recover permanent shape with some external stimulus – usually thermal
- Have potential for use as actuation material.



Xie and Rousseau, Polymer, 2007

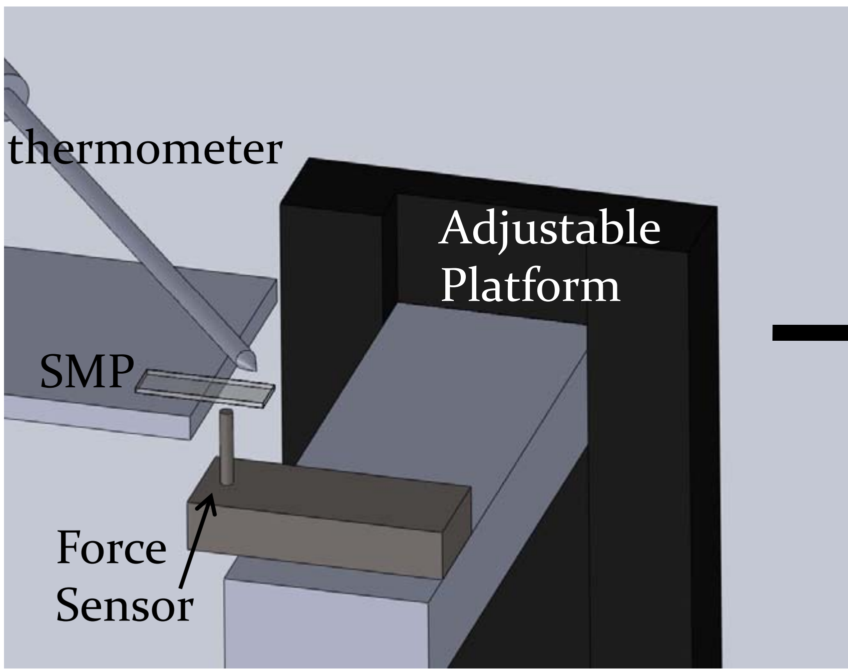
SMP Advantages

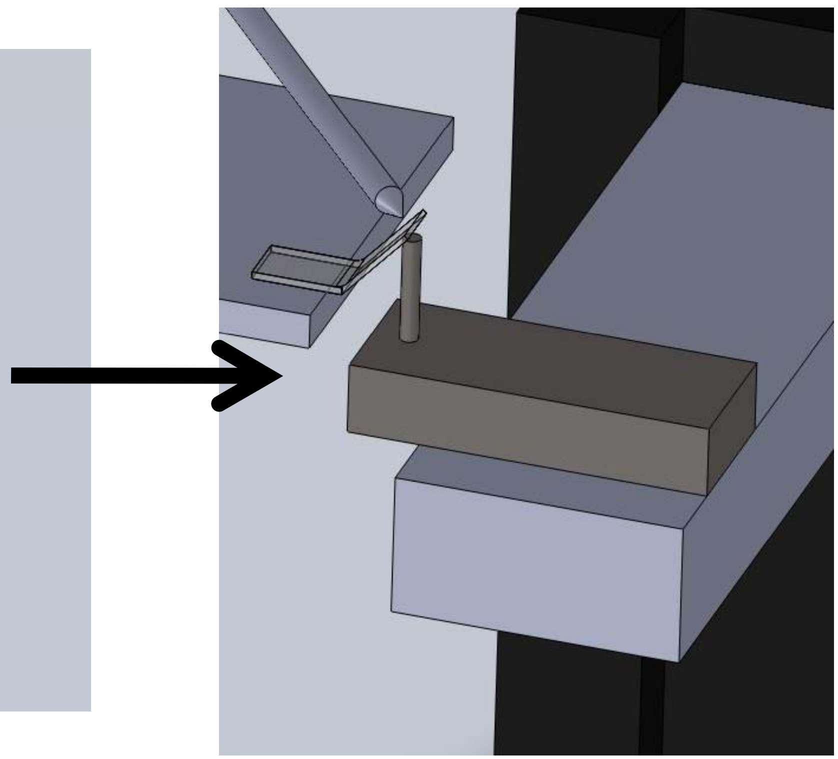
- Lightweight
- Low cost
- Flexible in terms of material design
  - Glass transition temperature (30°C to 89°C)
  - Mold Shape
- High recovery strain

SMP Fabrication

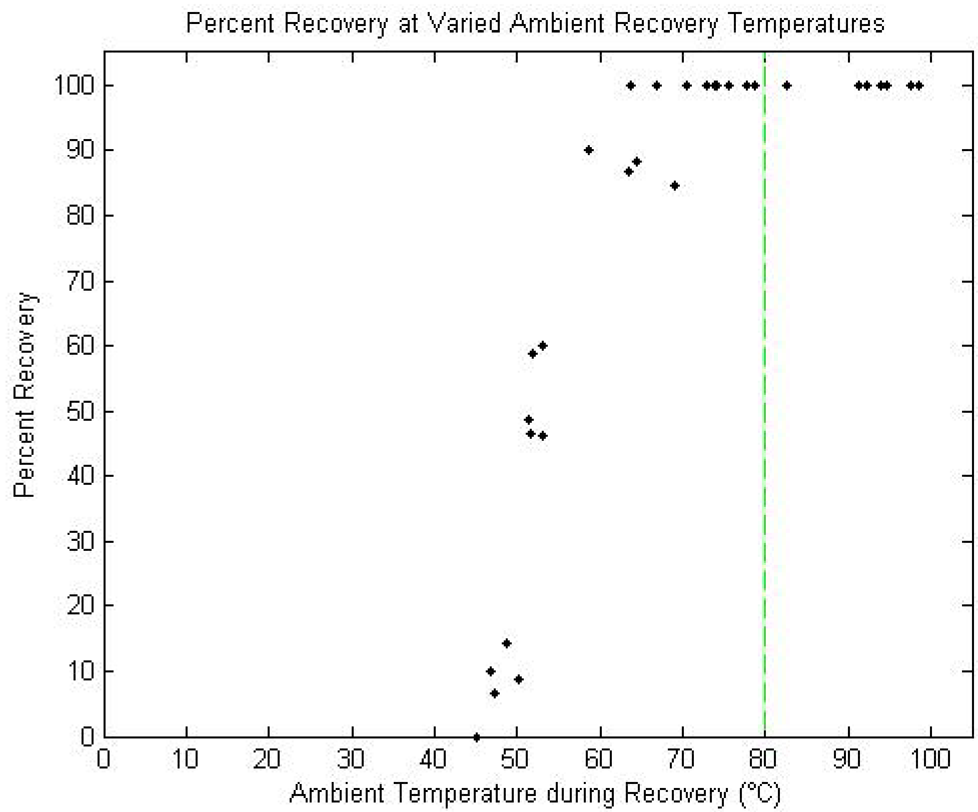
- Components:
  - 0.02 mol EPON 825 (an epoxy monomer)
  - 0.005 mol Jeffamine D230 (curing agent)
  - 0.01 mol decylamine (curing agent)
- Components were combined then poured into a mold and cured for 1.5 hours at 100 °C and then for 1 hour at 130°C .
- SMP with glass transition temperature of 80° C.

Percent Recovery Testing





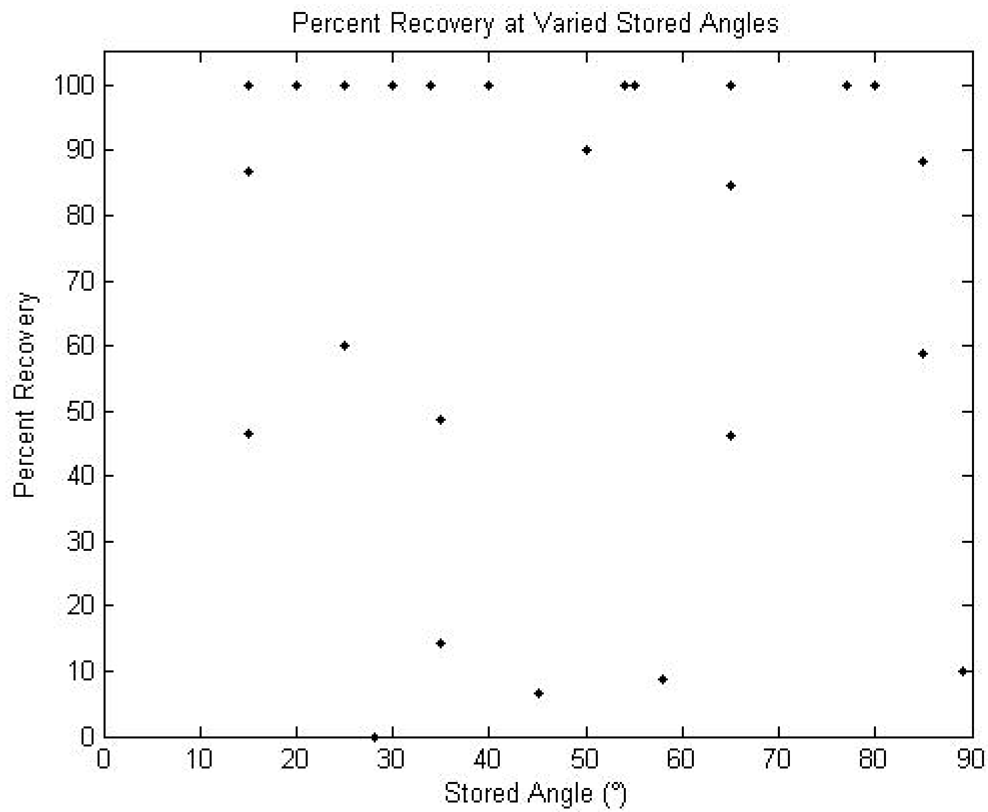
Percent Recovery Results



- 100% recovery consistently observed at temperatures above 70.5 °C

- Percent Recovery diminishes to zero by 45.5°C

Percent Recovery Results

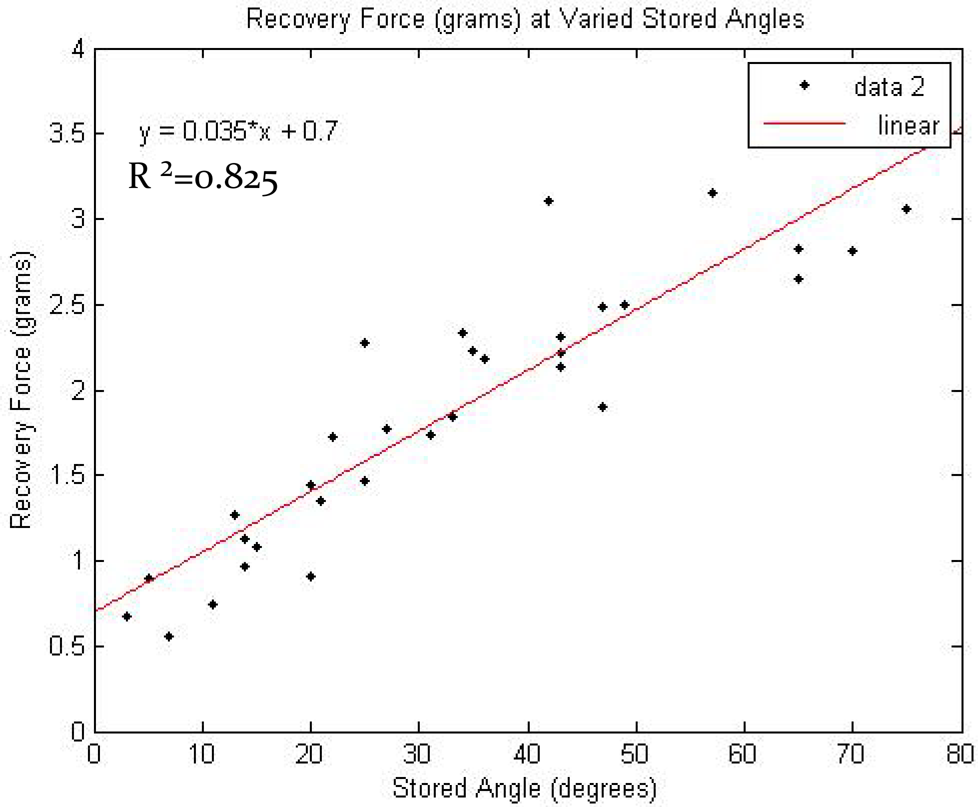


No correlation between stored angle value and percent recovery

Force Testing

- The force to deform the SMP and the force exerted by the SMP during recovery were measured using a force sensor.
- Force data was collected for a range of stored angles and recovery temperatures.

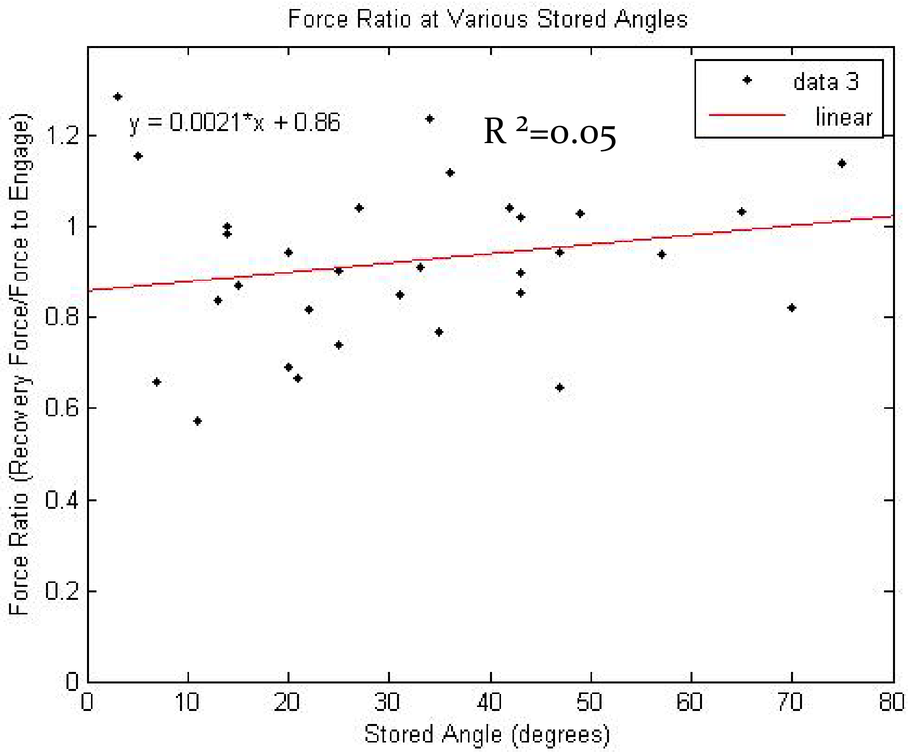
Force Testing Results



Recovery force increased with greater stored angle values.

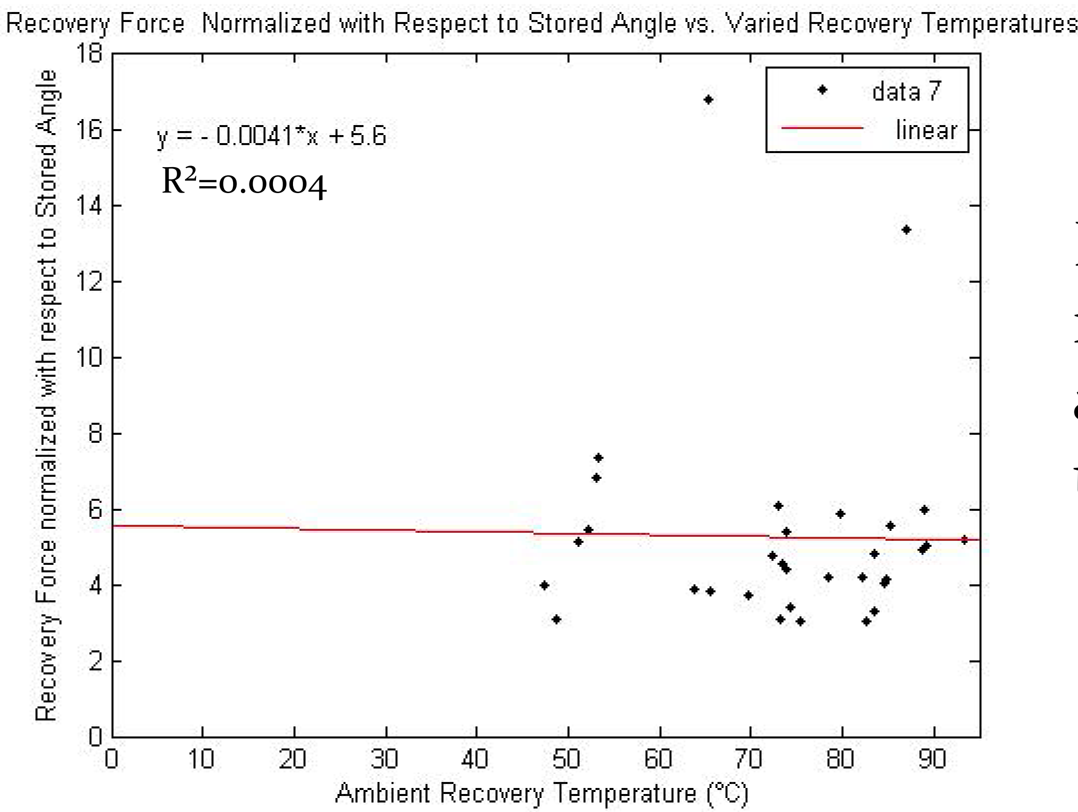
Force Testing Results

Force Ratio = (Recovery Force)/(Force to Engage)



- Efficiency will not increase with greater stored angles.
- Average force ratio = 0.9265

Force Testing Results



Recovery Force was not correlated to ambient recovery temperature

Static Friction Testing

- SMP samples were placed on a surface that was inclined until the SMP slipped.
- The angle at which slip occurred was used to calculate the static coefficient of friction μ.
- μ=tan(theta_slip)

μ,aluminum=0.61

μ,ABSsmooth=0.64

μ,ABSrough=0.62

SMP Gripper

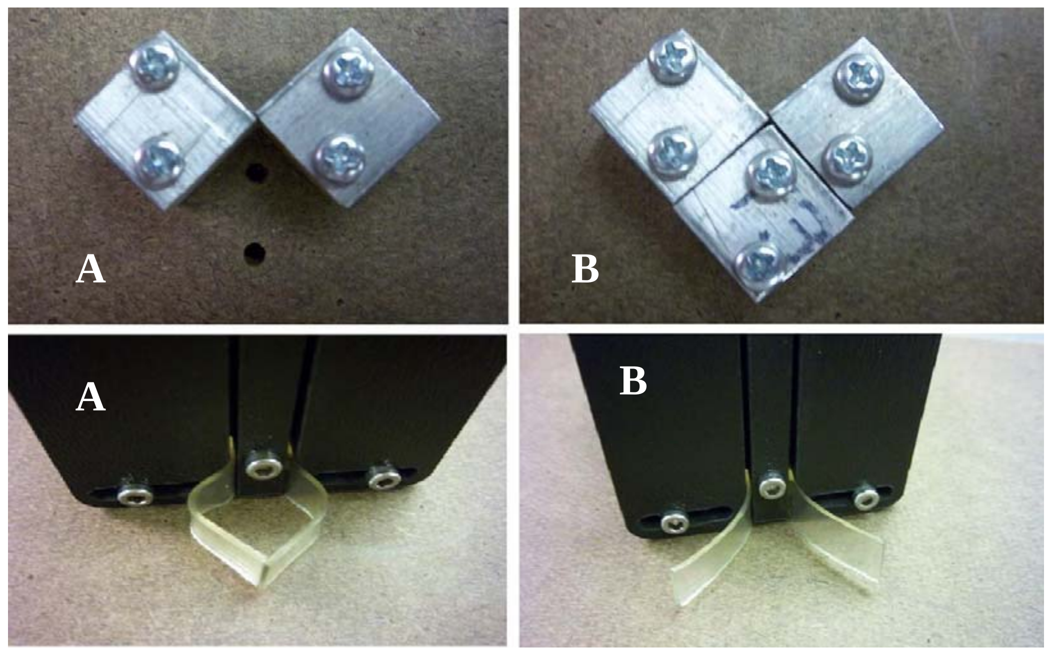
- A gripper compatible with Ckbot modules was designed and cut from ¼ inch ABS plastic.

- Based on force and static friction data, the weight the gripper would be able to lift was calculated
- Max weight = 2.02 grams
- Average weight = 1.19 grams

Opening the Gripper

Two configurations were used to deform open the gripper.

- Both configurations resulted in a successful lift of an object weighing one gram in 9/10 trials.



Video

Mini-PR2 robot using SMP gripper

Future Work

- Reversibility of Gripper
- Autonomous heating of SMPs
- Improve Strength of Gripper

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Questions?