# CPS: Ant-Like Microrobots

## Fast, Small, and Under Control

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## Objectives

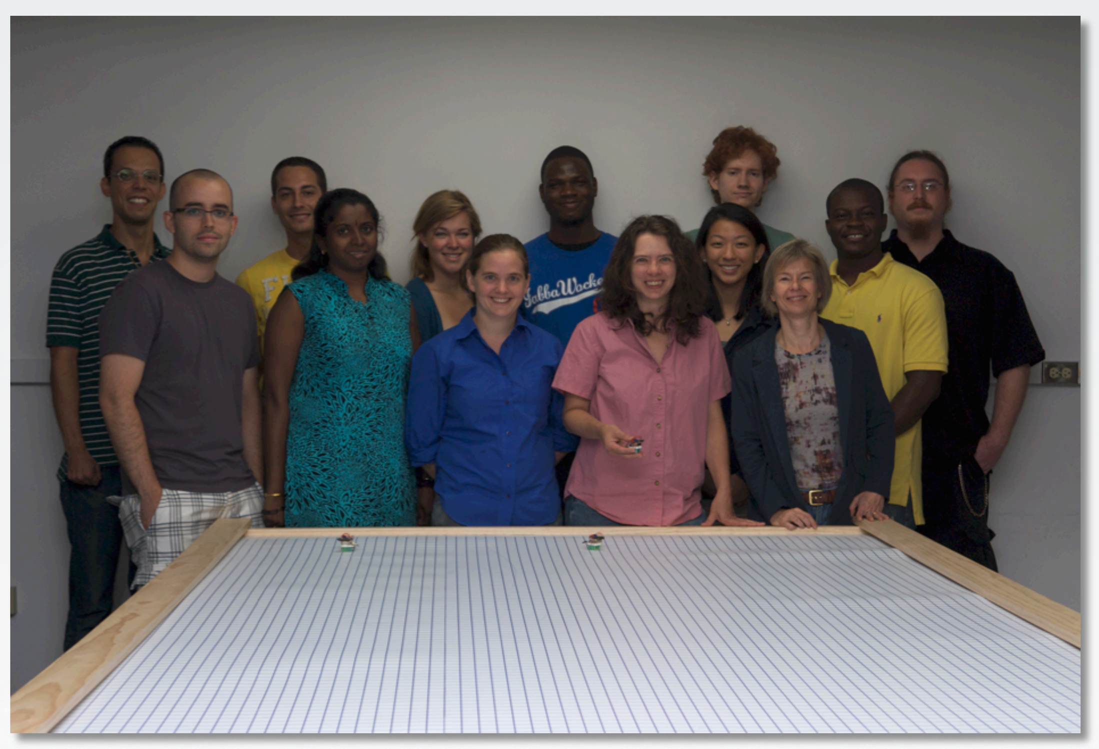
Development of the first wireless network of cooperative mobile autonomous robots at a very small scale.

### Research Goals

- Development of prototypes of micro and mini-robots featuring effective and power-efficient locomotion mechanisms, hybrid on-board processing (analog and digital), wireless communication, localization and inertial measurements.
- Design of new decentralized control and coordination algorithms using very low power, sparing communication and coarse localization and inertial measurements.

### Educational Goals

One of the main goals of the project is to expose undergraduate students to the research environment. To this end, there are currently seven undergraduate students collaborating with five graduate students on various aspects of the project.

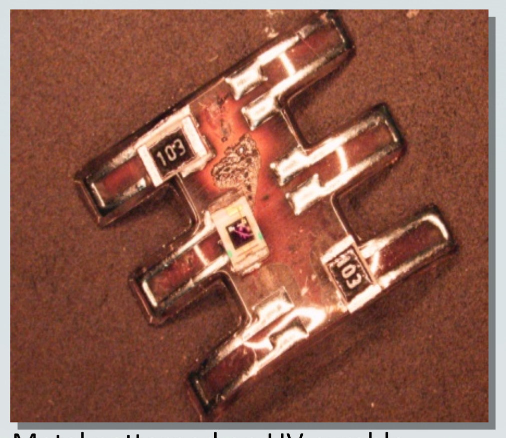


*Back row:* Dr. Nuno Martins, Mike Gateau, Kate Miller, Justin Pearse, Ken Tossel, Chris Perkins
*Front row:* Eduardo Arvelo, Bavani Balakrisnan, Dr. Sarah Bergbreiter, Dr. Pamela Abshire, Lydia Lei, Dr. Elisabeth Smela, Andy Hammond.
*Not pictured:* Tsung-Hsueh Lee, Michael Kuhlman

## Locomotion

### Thermal Bimorphs

We have begun the development of robot legs that twist to provide forward locomotion instead of the pure bending that is typical for a bimorph. Moreover, we have shown that we can integrate circuits using off-the-shelf components on-board these hexapod platforms by demonstrating a fully autonomous jumping microrobot.



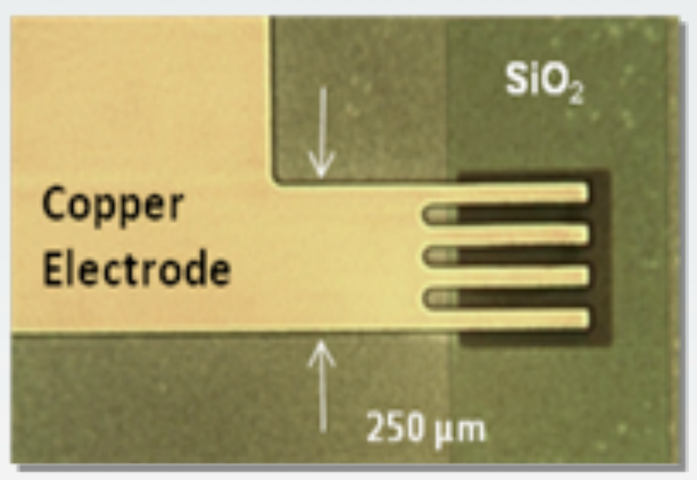
Metal patterned on UV-curable polymer in RAMP process showing thermally actuated legs.

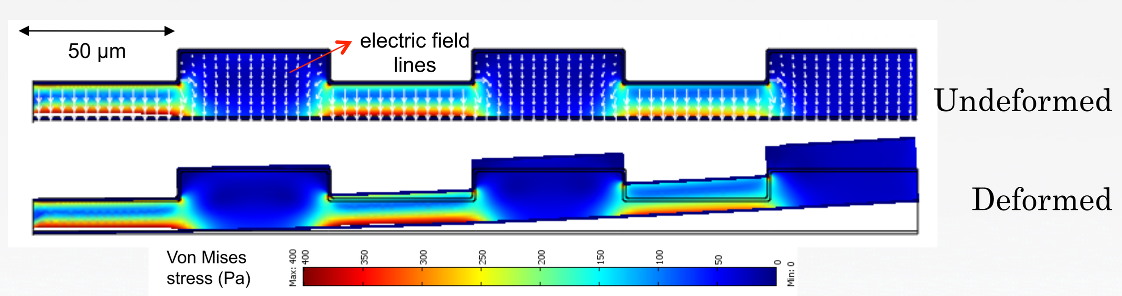
Integration of power and a control circuit for a jumping hexapod (this robot jumped 8 cm!).

### Dielectric Elastomer Actuators

Dielectric elastomer actuators (DEAs) have been demonstrated on the meso-scale, and their reported performance metrics are compelling. Therefore, we are developing methods to microfabricate DEAs. Furthermore, in order to optimize their design, finite element simulation was carried out using COMSOL.

Overhead view of four DEAs with a common top electrode.



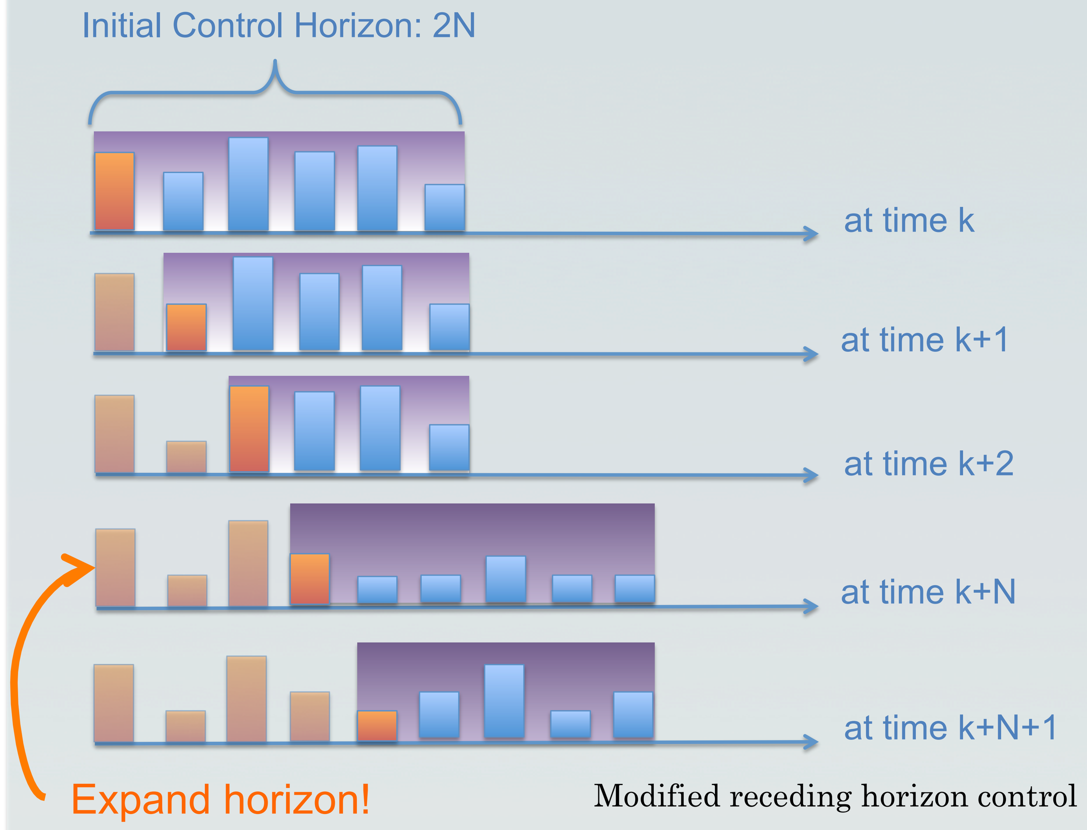




2D simulation result of crenellated bending DEA design.

## Control & Sensing

### Receding Horizon Control

In receding horizon control (RHC), an optimization is carried out for a finite horizon and the first calculated input is applied. Then the horizon is updated and the procedure is repeated. We employ a modified strategy depicted below that guarantees infinite horizon stability.




Modified receding horizon control

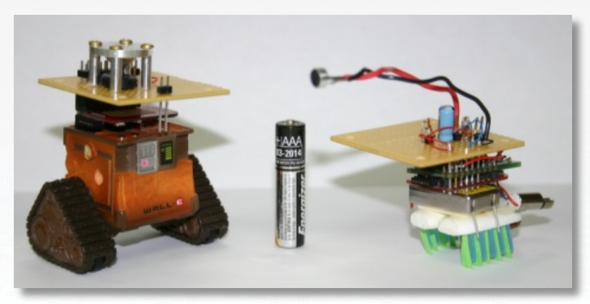
### Decentralized Control

Coordination and control strategies are being developed in a decentralized RHC manner, taking into account severe computational and communication constraints. Our algorithms based on dual decomposition methods also allow for "incremental robustness" (robustness to the addition and removal of agents).

### Sensing Methods

Distance between the mini-robots is measured using Received Signal Strength Indicator (RSSI) and Time Difference of Arrival (TDOA) methods. Results indicate that TDOA is more robust, although it requires more hardware.

Two mini-robots with RSSI and unidirectional TDOA sensing capability (sound source left, microphone right), AAA battery shown for size.



## Testbed

A testbed has been created in the Cooperative Autonomy Laboratory at UMD. It consists of a $5m^2$ platform, an overhead camera, and a computer, which connects to each of the robots wirelessly.

### Tracking System and Zigbots

Since the algorithms will be first implemented in a centralized manner, a vision-based tracking system has been developed for coordination. At a later stage, the tracking system will be used to validate decentralized strategies. We have also built a swarm of Zigbots.

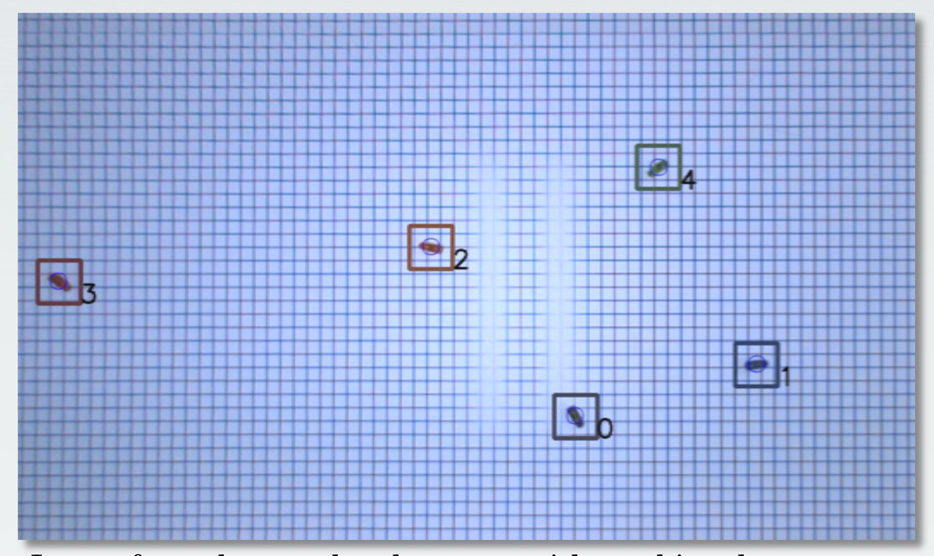



Image from the over head camera with tracking data overlay. The tracking data will be used in the centralized coordination algorithms and, later, for the validation of decentralized strategies.

Fleet of Zigbots: these robots are built using toothbrush heads, pager motors, a ZigBee board and a battery. As the motors vibrate, the rear-angled bristles bend and move the robots forward. Two motors can steer the robots left and right.