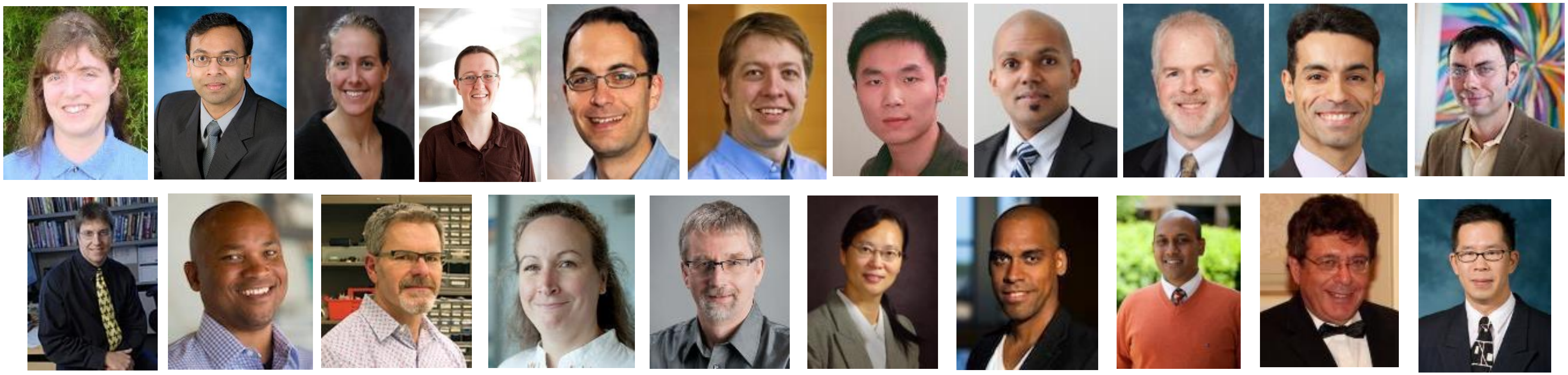
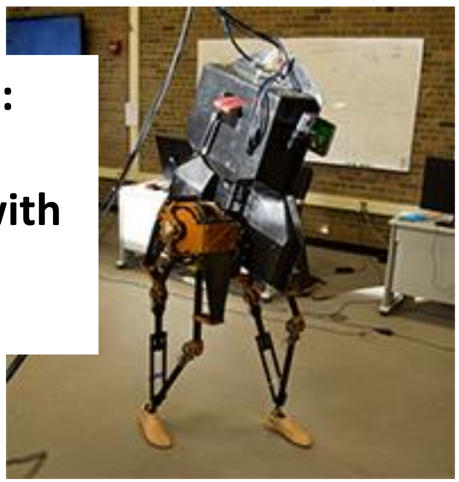


Robotics

http://robotics.umich.edu

Robotics at Michigan

35+ faculty in Aerospace, Biomedical, Civil, Computer, Electrical, Industrial, Mechanical, Marine Engineering engaged in robotics



MARLO: Bipedal robot with full 3-D motion

Intelligent Wheelchair

MAGIC 2010 Champions

Flying Fish

Rehabilitation Robotics

Active Safety and Driver Assist w/Ford

Full-Spectrum Robotics

- Robots that walk, fly, drive, and swim
- Robots sense their environment and communicate with each other and humans
- Explosions in sensing technology, in algorithmic potential for extracting information from the sensed data
- Robots connected to the “cloud” via the Internet of Things

This is Michigan Robotics

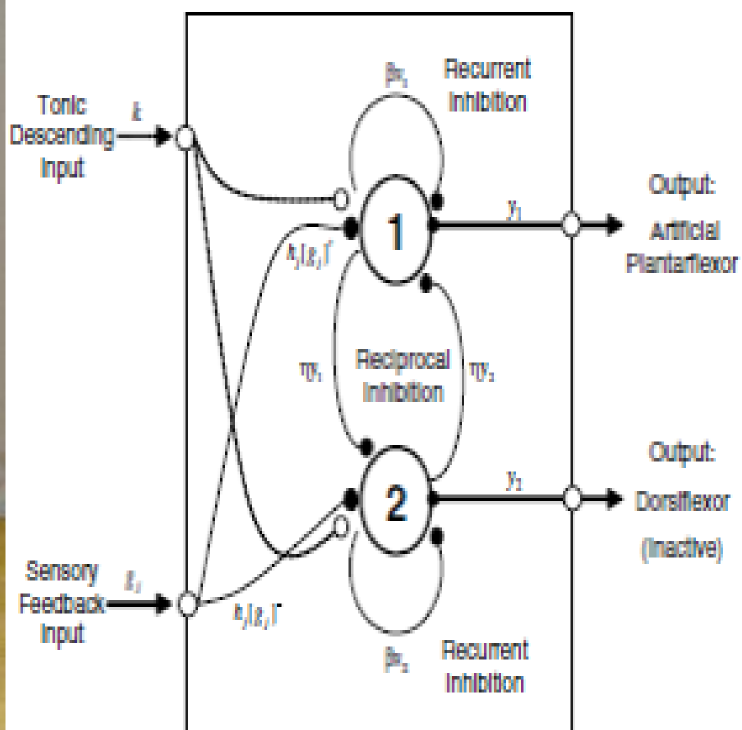
Full-Spectrum Robotics

- Prosthetic limbs link with the human brain to restore function for stroke patients and accident victims
- Driverless cars will save tens of thousands of lives every year
- Autonomous submarines will map the ocean floor and inspect ships' hulls for cracks and other dangers
- Walking robots will assist humans with search-and-rescue tasks

Dan Ferris, BME and Kinesiology

Lower Limb Exoskeletons

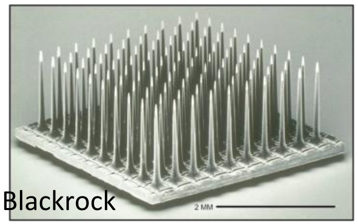
Bionic Lower Limb Prostheses



Artificial Neural Oscillator Controllers

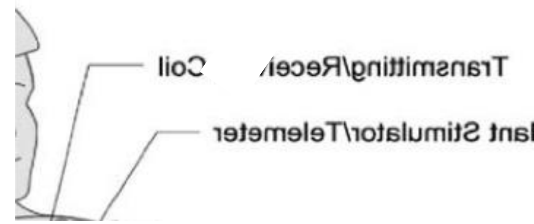
Cortical Neural Prostheses Lab
Cynthia Chestek, BME

Multi-Electrode Arrays



Motor Cortex

Functional Electrical Stimulation
(Peckham, Kilgore, et al.)



Bkin Exoskeleton

Articulated Prostheses

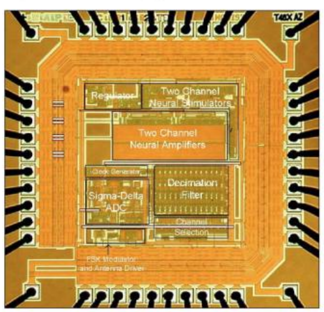
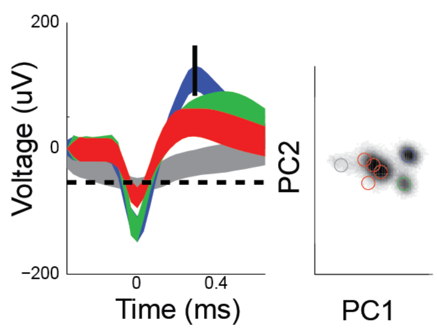


Figure 5. Die microphotograph.

Custom Electronics



“Decoder” Algorithms

Full-Spectrum Robotics

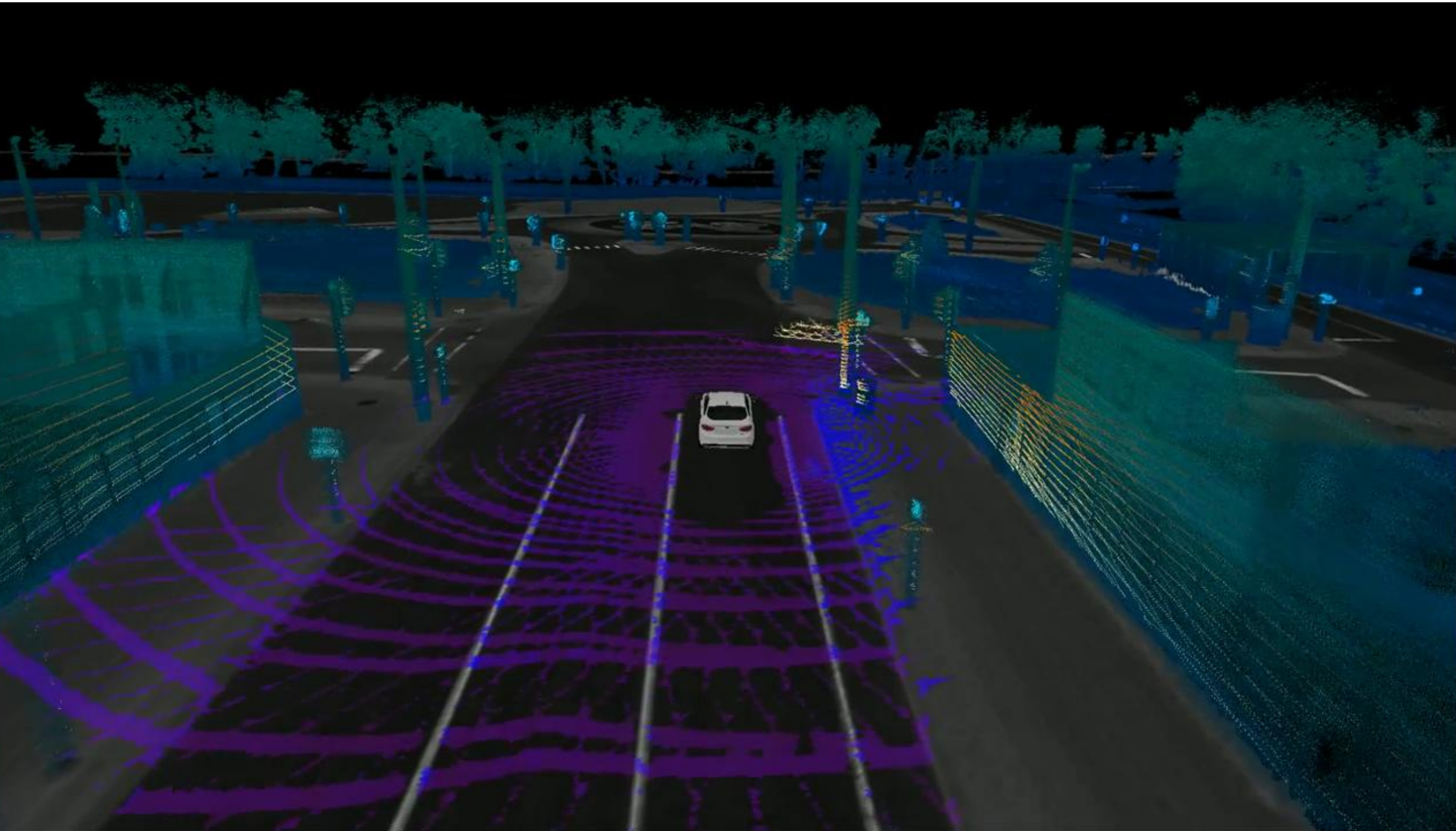
- Prosthetic limbs link with the human brain to restore function for stroke patients and accident victims
- Driverless cars will save tens of thousands of lives every year
- Autonomous submarines will map the ocean floor and inspect ships’ hulls for cracks and other dangers
- Walking robots will assist humans with search-and-rescue tasks

Open-AV

M
city
UNIVERSITY OF MICHIGAN
UNITED STATES DEPARTMENT OF TRANSPORTATION

MCity

MCity



Full-Spectrum Robotics

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- Walking robots will assist humans with search-and-rescue tasks

Ryan Eustice and Matt Johnson-Roberson
Naval Architecture and Marine Engineering (NAME)

Science: Great Lakes and ocean mapping

Education: Students of today – Leaders of tomorrow

Defense: Autonomous ship-hull and harbor inspection

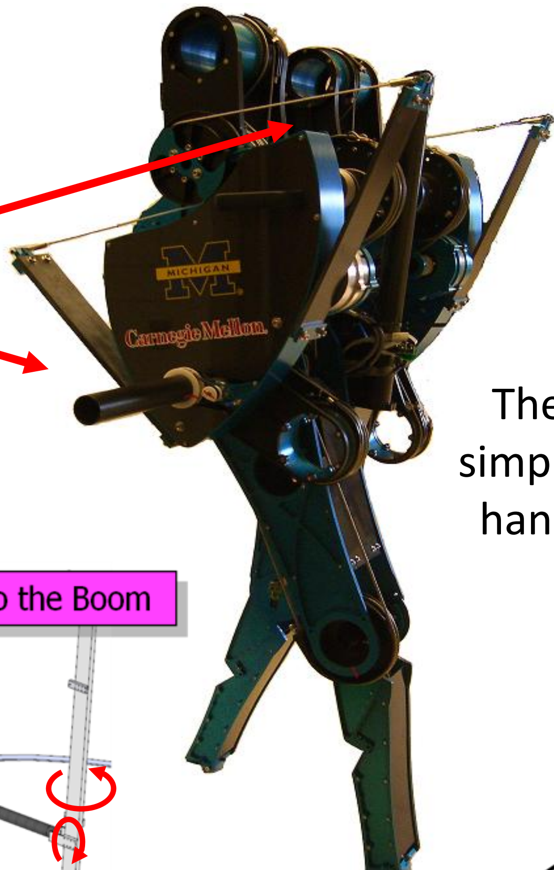
Underwater Archaeology

Full-Spectrum Robotics

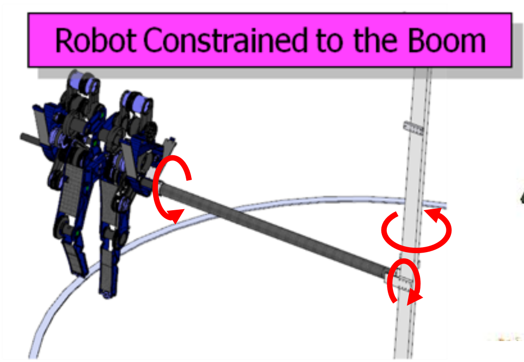
- Prosthetic limbs link with the human brain to restore function for stroke patients and accident victims
- Driverless cars will save tens of thousands of lives every year
- Autonomous submarines will map the ocean floor and inspect ships’ hulls for cracks and other dangers
- Walking robots will assist humans with search-and-rescue tasks

Bipedal Locomotion via Geometric Control
Jessy Grizzle, ECE

MABEL: The World's fastest running robot with knees



Large Springs

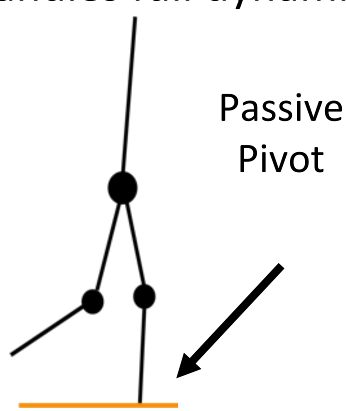


Research Goals: Model-based control solutions for walking and running

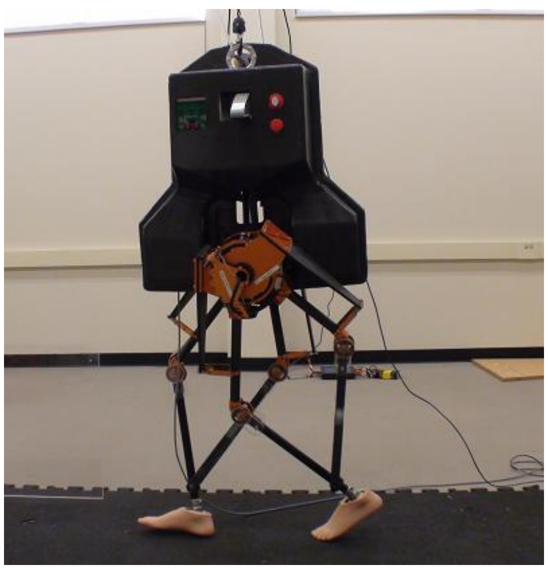
Disturbance rejection – uneven terrain (step-up and step down)

Agility and Stability

Theory started with simple models and now handles full dynamics

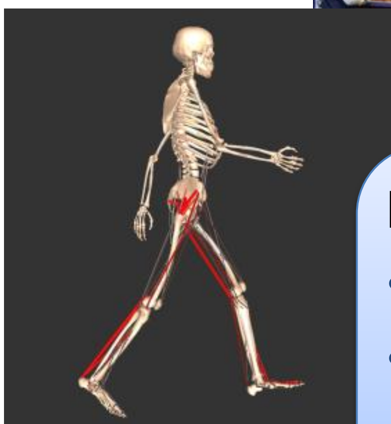


Meet MARLO: Free-running biped, joint project with CMU and Oregon State

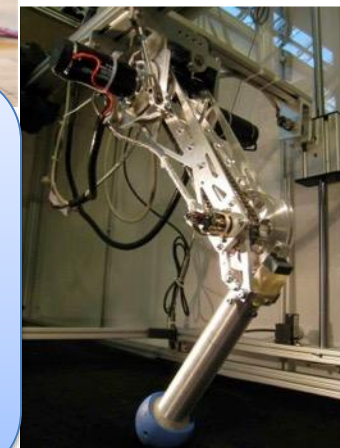


Robotics and Motion Laboratory
C. David Remy, ME

Locomotion in Nature

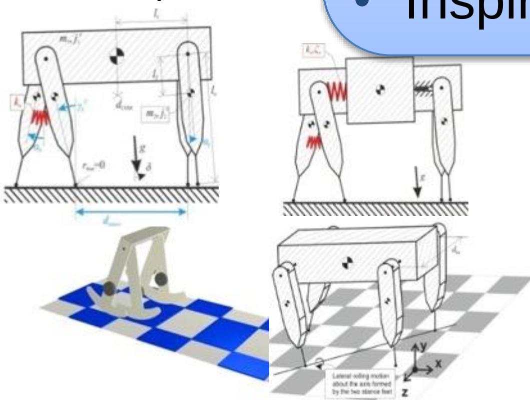


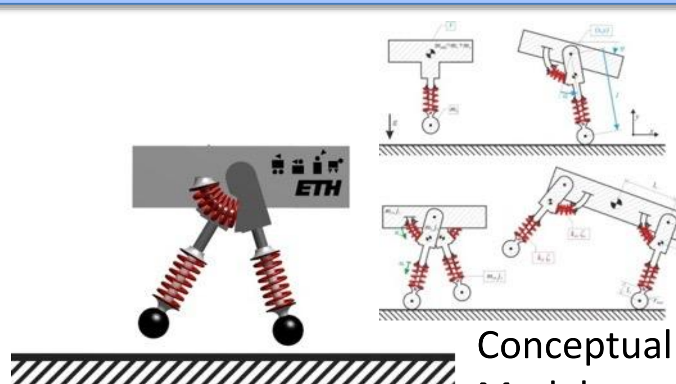
Hardware Implementation



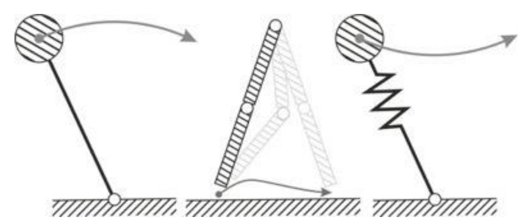
Research Goals:
- Exploitation of Natural Dynamics
- Design, Control, Optimization of (Legged) Robotic Systems
- Inspiration from Biology and Biomechanics

Passive Dynamics





Conceptual Models



Natural Dynamics

MARLO

Biped Robotics@Michigan
1.0 RABBIT
2.0 MABEL
3.0 ATRIAS
MICHIGAN
ENGINEERING
Bipedal Robot
Lab

Intellectual and Academic Vision for a Robotics Institute

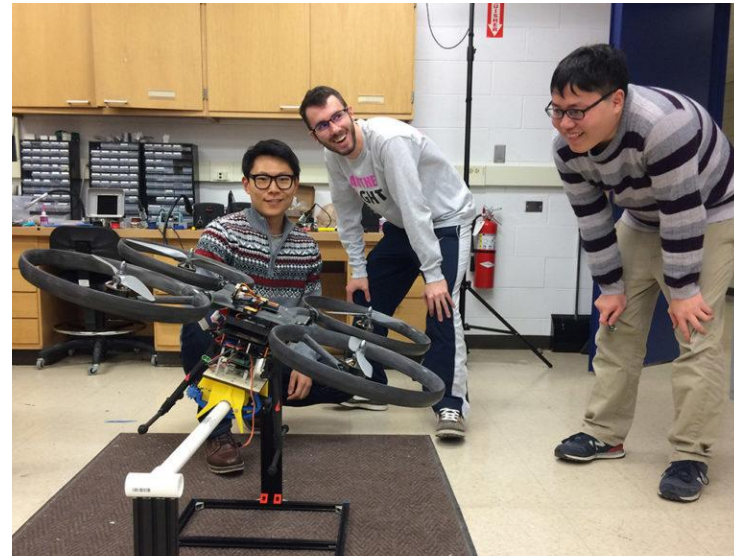
- Robotics = design, creation, analysis, and use of embodied computational systems that interact with the human and physical environment
  - Computer Science, Mechanical Engineering, Electrical Engineering, Control, Psychology, Human-Robot Interaction, Sociology, Ethics, Law, Biomedical Engineering, Medicine, Business, Policy,…

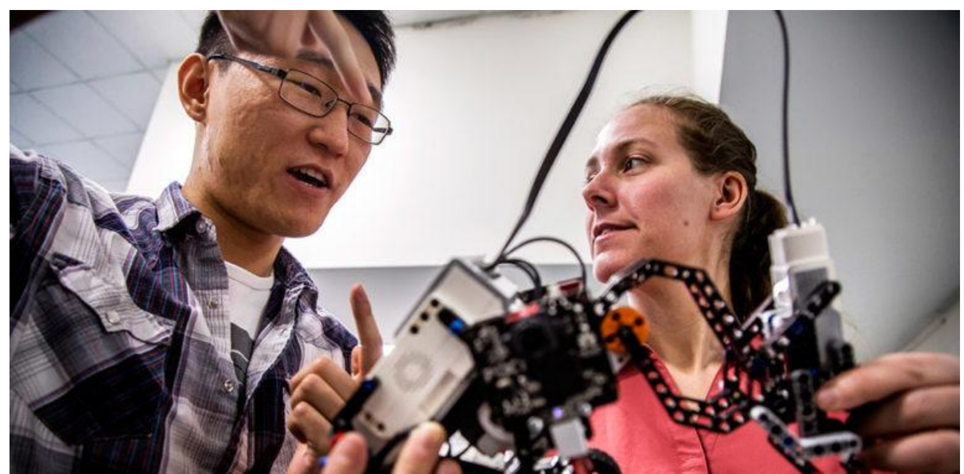




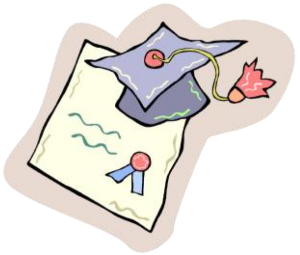
Robotics focus areas

- Autonomy, reasoning, and learning
- Biomedical and rehabilitation robotics
- Control: Manipulation and Mobility
- Human-Robot Interaction
- Manufacturing
- … many more possible





Educational Vision

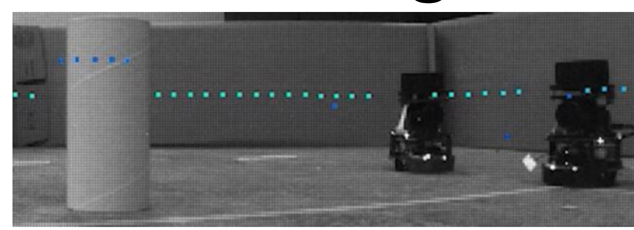


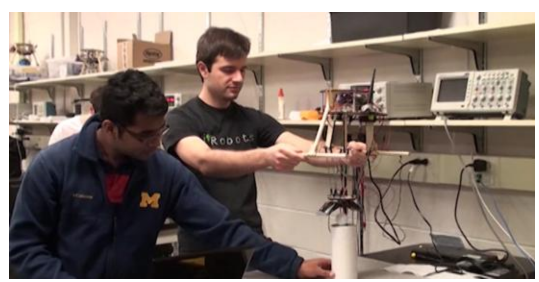
- New Robotics PhD program Fall 2014 aligned around three core disciplines:
  - Sensing (perception, mapping, computer vision, signal processing)
  - Reasoning (planning, multi-agent coordination, artificial intelligence)
  - Acting (kinematics, dynamics, manipulation, mechatronics, and control)

- High interest to students, growing quickly!
  - 5 new PhD and 3 MS students in 2014
  - 6 new PhD and 14 MS students in 2015
  - 12 new PhD and 35 MS students in 2016

Two new courses

- ROB 501: Math for Robotics
- ROB 550: Robotic System Laboratory
  - Lab with electronics workstation and 3D printer open 24 hours a day.
  - Support from full-time robotics lab engineer
  - 3 separate platforms: ground, air, manipulator





New Robotics Laboratory!

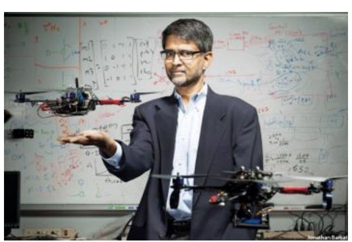
- Shared research labs: Walking robots, flying robots, autonomous cars, …
- Classrooms and instructional labs
- Faculty & graduate student offices
- 4th floor collaboration with Ford

M • Robotics

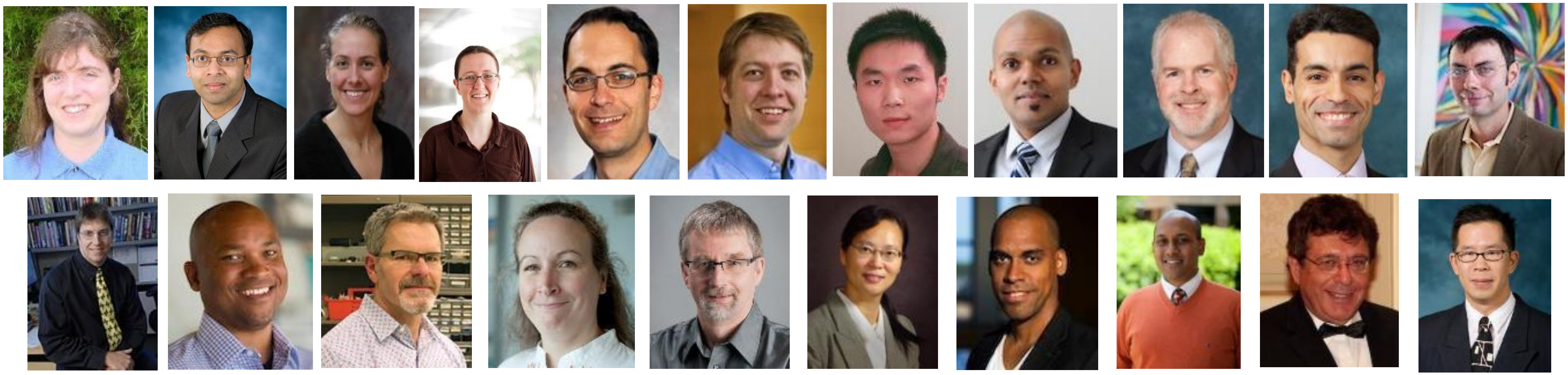
Activities of the Robotics Institute

- Robotics Day – annually with NCMS
  - 150 attendees in 2011
  - 594 attendees in 2015
  - 800 attendees in 2016!
  - Industry, High school (FIRST), Universities, Government
- Student group programs
- Seminar series:







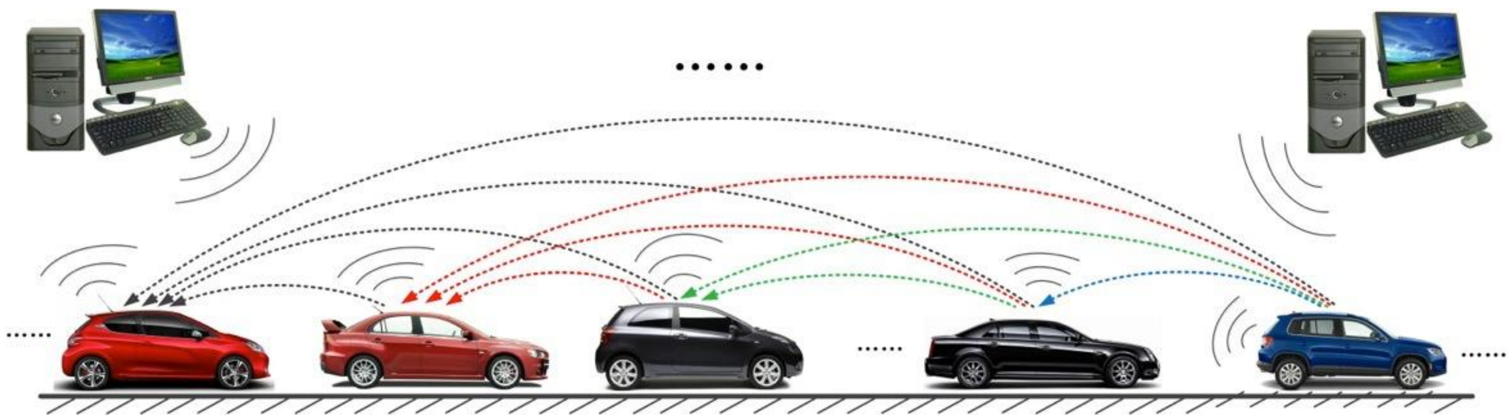
M Robotics

http://robotics.umich.edu

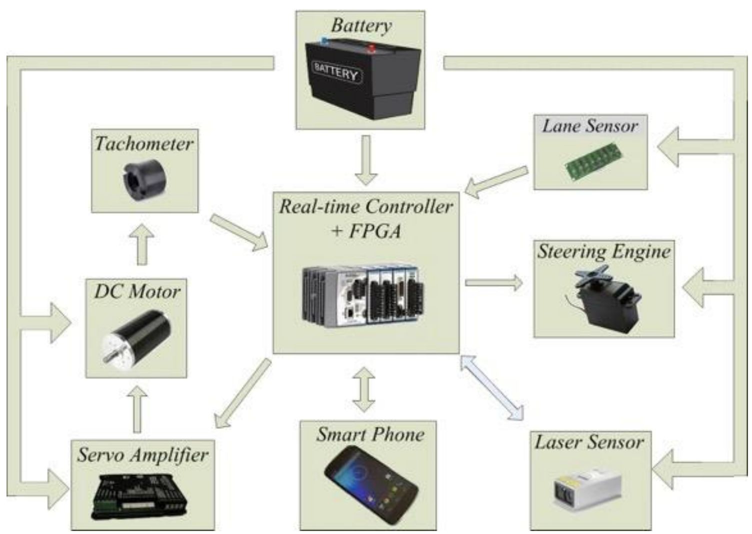
Excellence and Breadth in Robotics Research

M•Robotics

Orosz Ground Robotics Experiment (OGRE)
Gabor Orosz, ME



A testbed of unmanned ground robots to emulate a network of automobiles

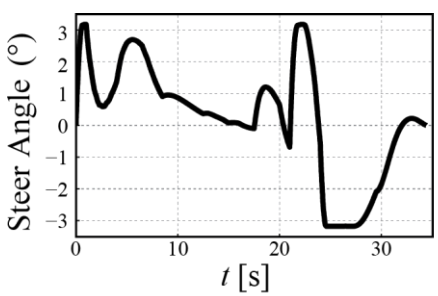


Emulate gasoline and hybrid powertrains via DC motors. Implement different sensing technologies.

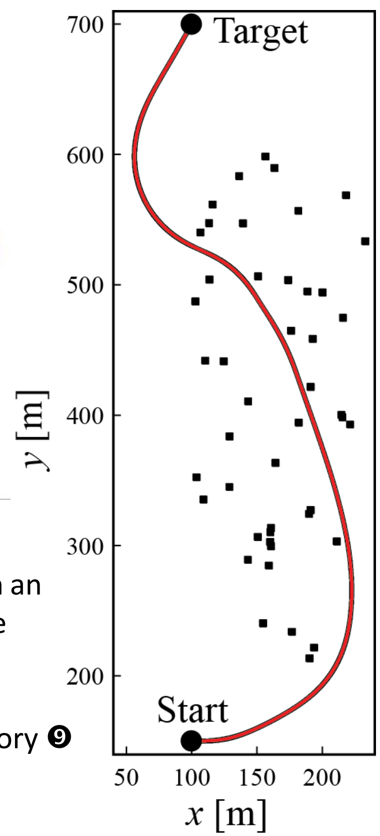
Research Goals: Study effect of limited bandwidth and time delays on sensing and communication. Study the collective motion of vehicles in single-lane and multi-lane configurations.

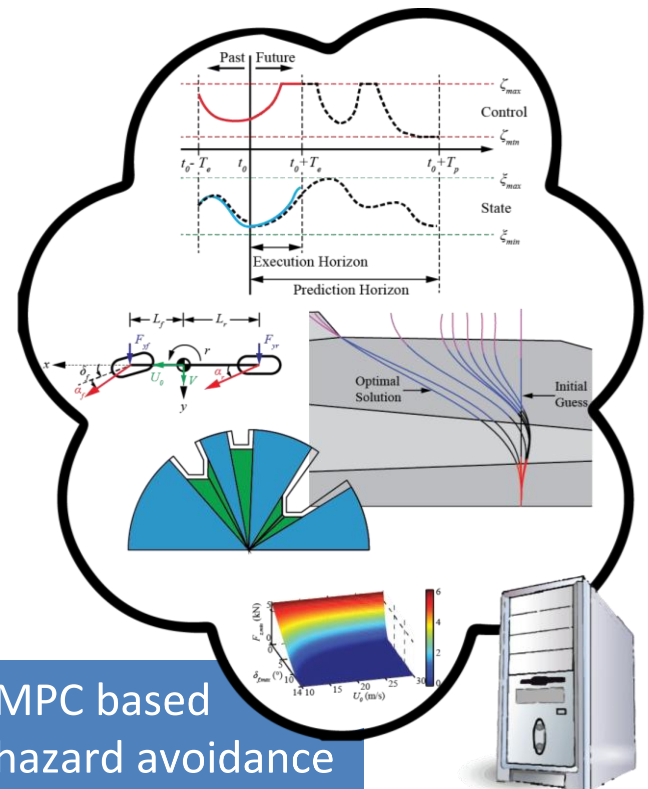
Real-time Hazard Avoidance
Jeff Stein and Tulga Ersal, ME

Research Goals: Develop a hazard avoidance algorithm for high-speed large-size autonomous ground vehicles using the model predictive control that takes vehicle dynamics into account and generates optimal maneuvers to avoid obstacles detected by on-board sensors



Navigation through an unstructured dense obstacle field.
← Steer angle
Trajectory ➒





MPC based hazard avoidance algorithm

Autonomy, Perception, Robotics, Interfaces, Learning (APRIL)
Edwin Olson, CSE

Automotive Safety:
- Planning and Control
- Perception is the key!

MAGIC: Multi-Robot Coordination with humans in the loop

Research Goals: Creating Effective Human-Robot Teams through improved autonomy, multi-agent planning and coordination, perception and situational awareness, command expression, and teaching

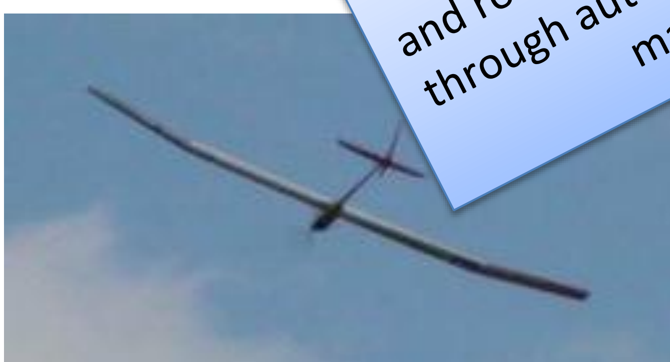
2010 World Champs!

Experimental Unmanned Aerial Systems Ella Atkins, Aero

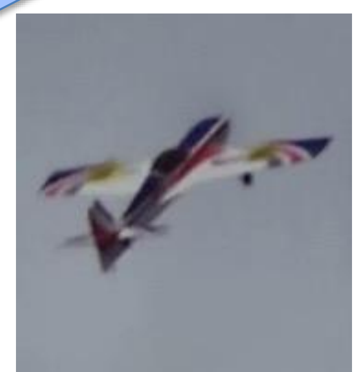
MAAV Student Team
(UAS risk analysi

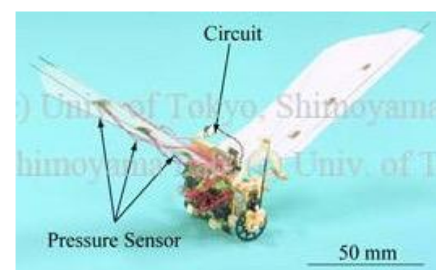
Flying Fish Seaplane UAS
(autonomous multi-flight management)

Research Goals: improve safety and robustness of robotic systems through autonomous contingency management



Solar Drones Student Team
(long-endurance small UAS)





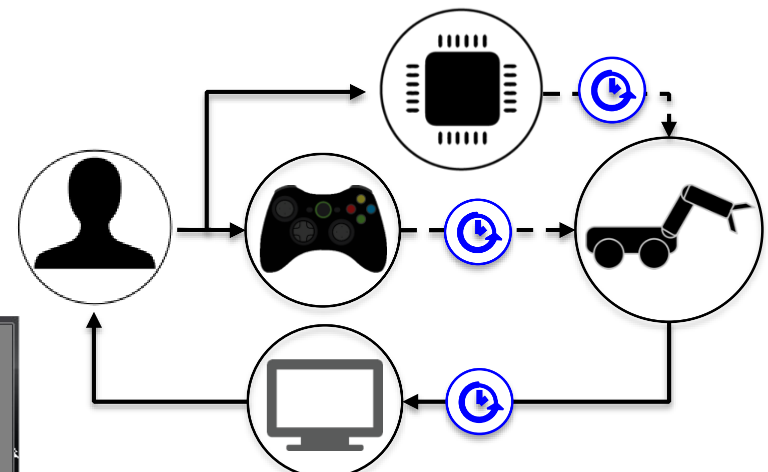
Embedded Aerodynamic Sensing (flapping and fixed-wing)

Improving Robot Teleoperation
Dawn Tilbury, ME

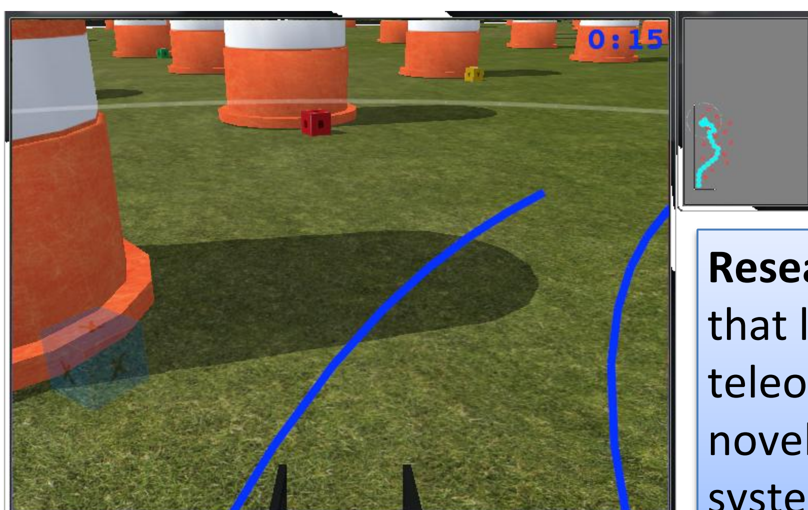
Sharing control between human and autonomy → maintaining safety while listening to human

A manipulator arm can be used to maintain rollover stability during high-speed maneuvers

Teleoperation performance with variable delays can be related to constant delays



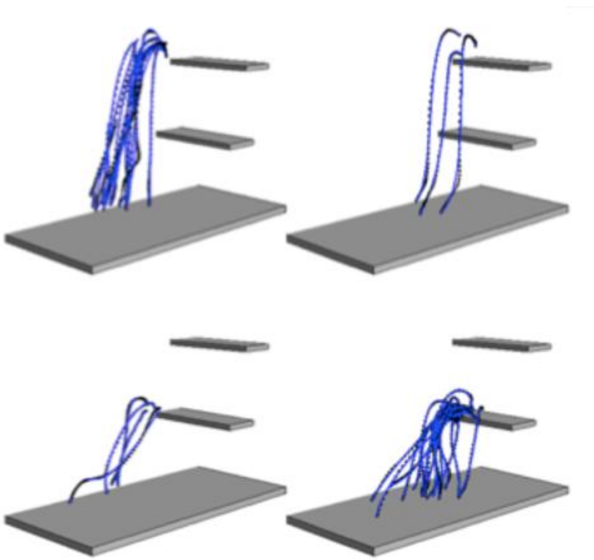
Obstacle avoidance and predictive displays can assist human operators



Research Goals: Characterize the factors that limit the speed and performance of teleoperated mobile manipulators. Develop novel control methods to improve overall system performance.

Human-Robot Collaboration
Matt Reed, IOE, UMTRI

Inferring Intent from Human Movement Patterns



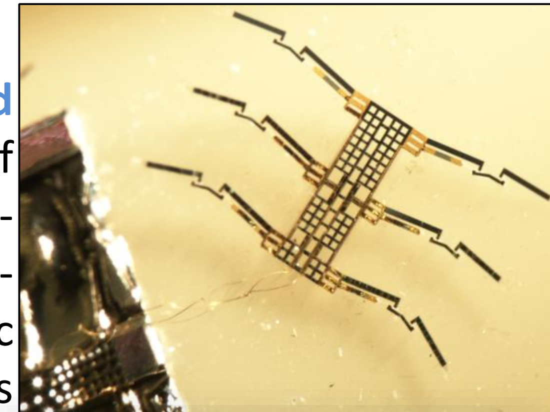
Learning to Use Human Tools

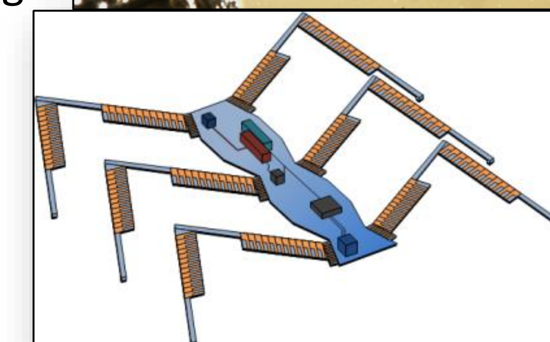
Predicting and Classifying Movement Patterns

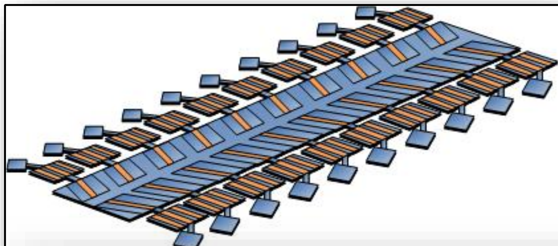
Research Goals: Improving human-robot collaboration through application of knowledge regarding human motor control and movement patterns.

Micro-Robotics
Kenn Oldham, ME

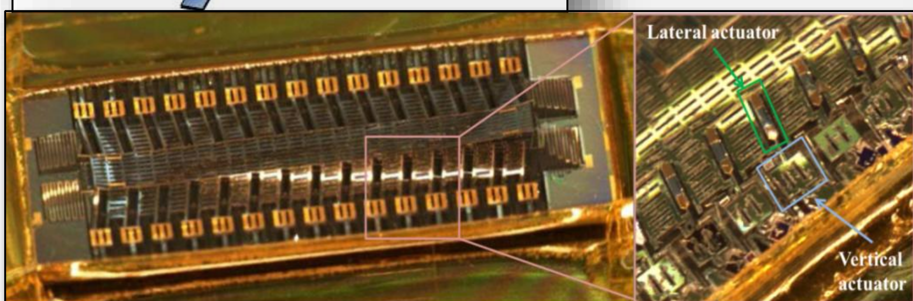
Design and fabrication of robust, high-mobility micro-robotic appendages

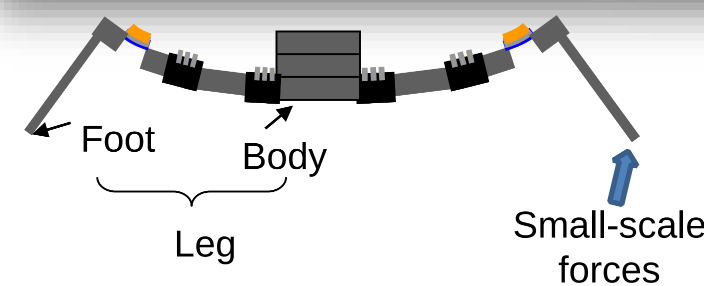




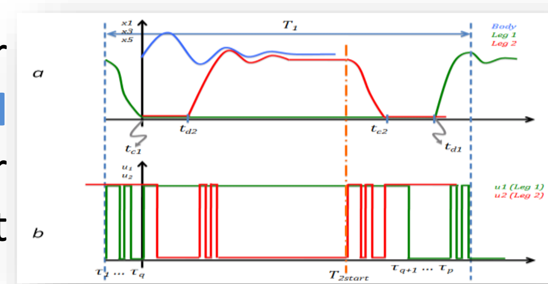


Dynamic modeling of micro-robotic motion



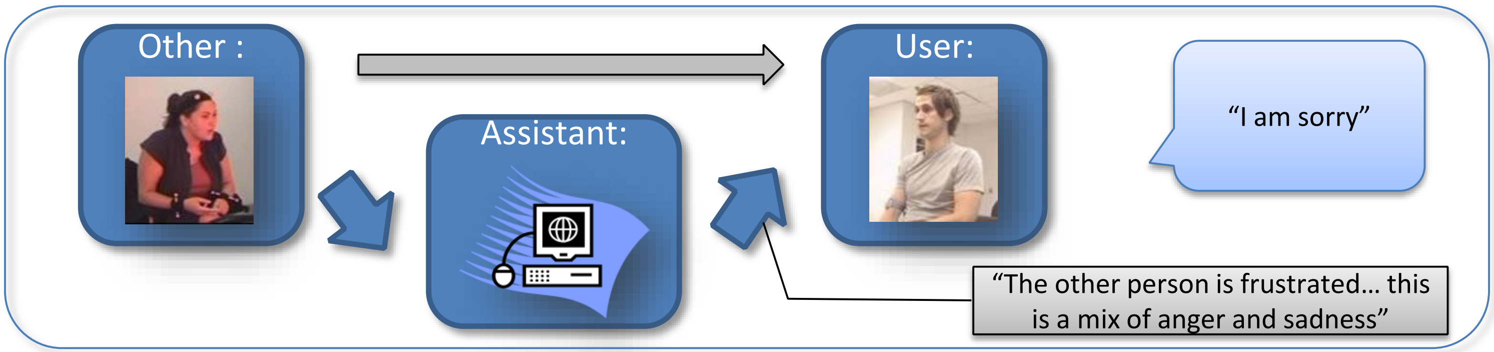


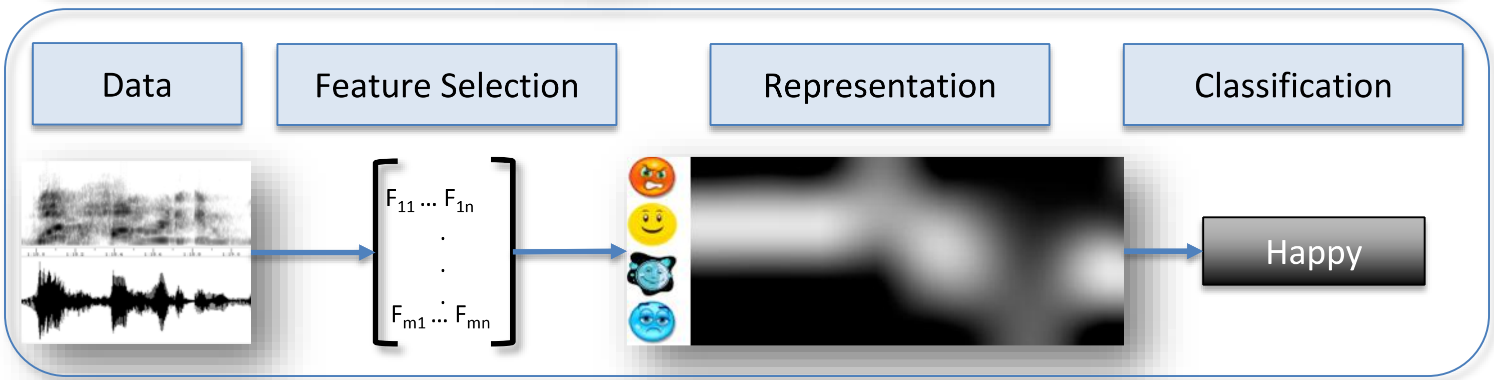
Ultra-low-power motion control and power management



Modeling and Quantifying Audio-Visual Expressions of Emotion

Emily Mower Provost, CSE



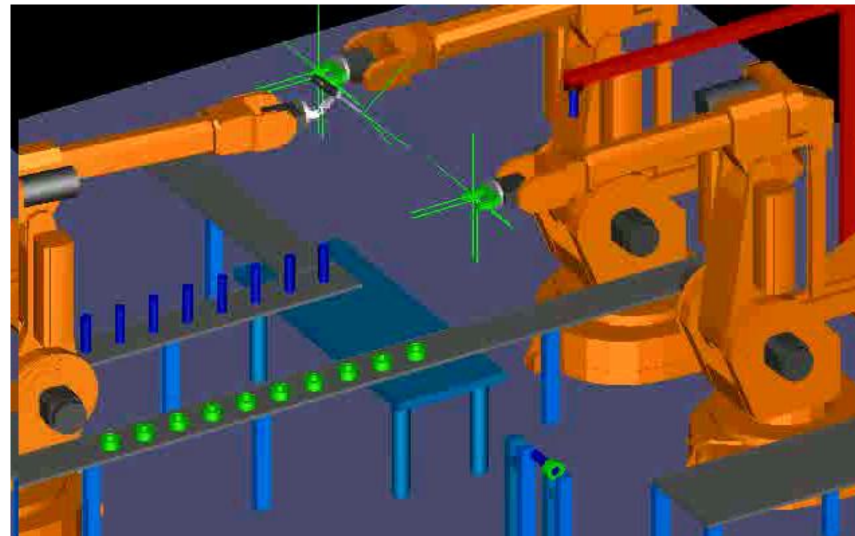


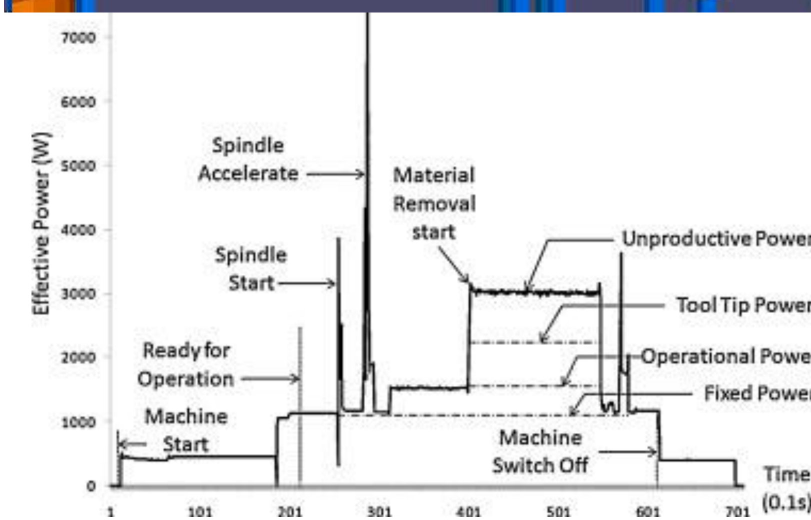
Research Goals: Mathematically characterize emotion structure, and estimate perception and perception change. Use speech processing to understand conversational dynamics. Understanding of human emotion to improve Human-Robot Interaction.

Multi-Robot Coordination and Task Scheduling Kazu Saitou, ME

Research Goals: Reduce total energy consumption and peak energy demands in multi-robot cells

- Arm posture optimization to minimize idle time energy consumption
- Multi-robot coordination to maximize the use of regenerative energy from one robot in other robots
- Task scheduling to reduce the need of rapid acceleration
- Task scheduling to spread energy peaks in multiple robots across cycle time





Power profile of typical operation exhibiting multiple energy peaks during cycle time (Duflou, et al, 2012)

Precision Motion Control for High-Speed, High-Resolution Manufacturing (Barton Research Group)

Goal: Design advanced sensing and controls algorithms for high precision motion control

Iterative Learning Control

- Flexible learning strategies
- Robust learning for a range of applications
- Cooperative learning control strategies

Advanced Sensing Strategies

- High-resolution sensing techniques
- Atomic force microscopy for topographical and charge density sensing
- Vision-based detection

Applications

- Emerging manufacturing processes
- High-resolution, high-speed manufacturing systems
- Rehabilitation robotics
- UAVs and other autonomous systems

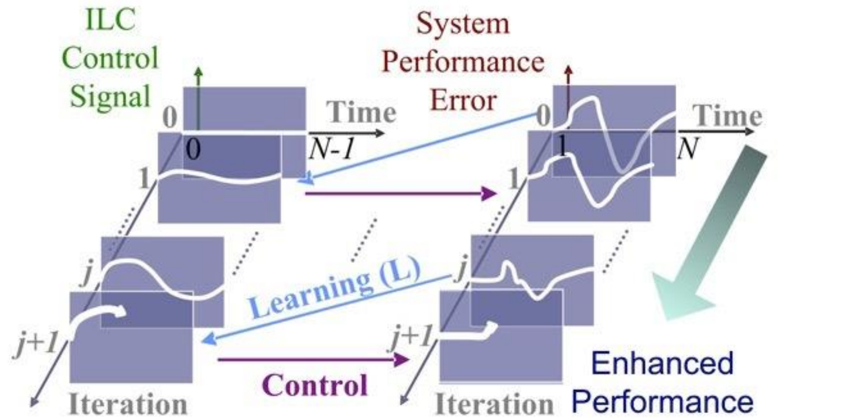


Fig. 1: ILC process - As the number of iterations increases, the feedforward time domain control signal is determined and the error signal is minimized.

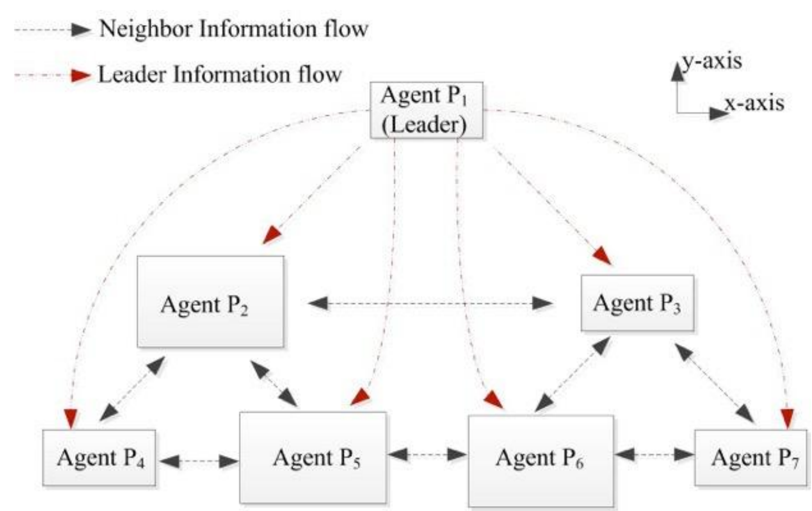
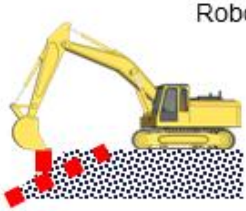


Fig. 2: Cooperative learning strategies - Develop cooperative learning control techniques to enable efficient and effective surveillance and monitoring operations.

Laboratory for Interactive Visualization in Engineering (LIVE)

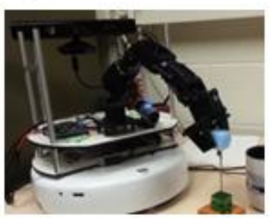
Construction Automation and Robotics

Robot Planning

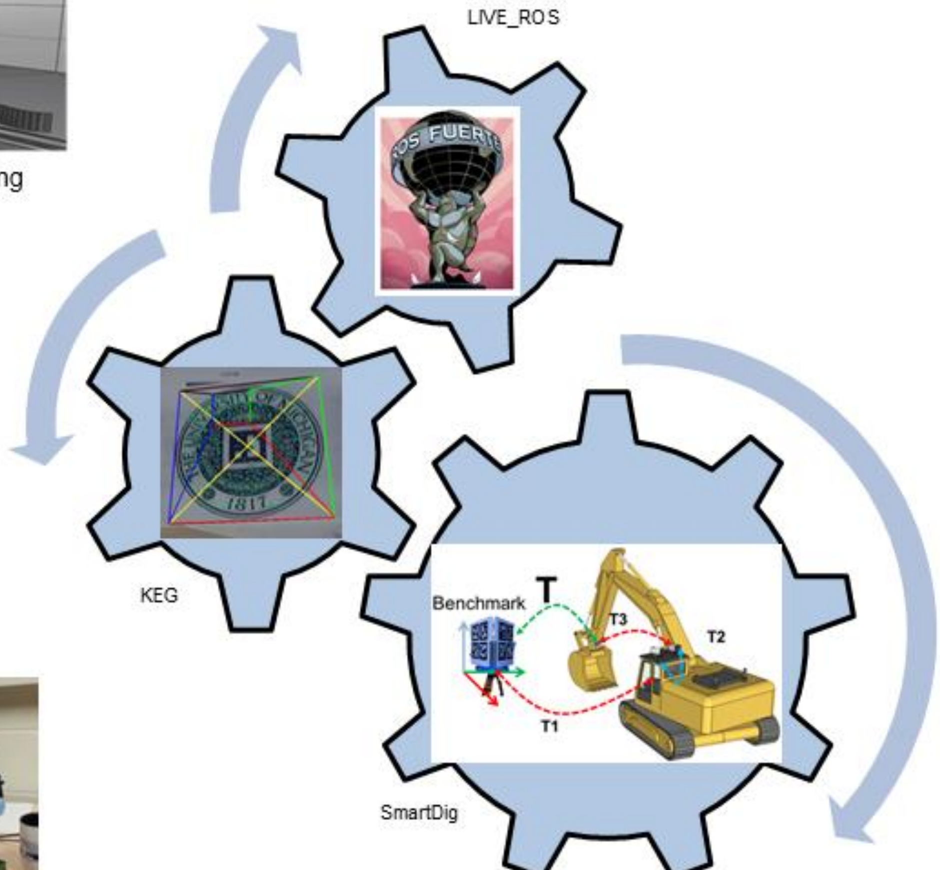


Robot Pose Estimation

Robot Navigation



Robot Manipulation



Excavation and Mining

Building Construction

Operations and Maintenance

Social Robotics

Basic Research → ***Innovations*** → ***Applications***

Professor Vineet R. Kamat, Ph.D.

Associate Professor of Civil Engineering

University of Michigan

This work is supported by the National Science Foundation (NSF) through grants CMMI-1265733, 1160937, and 927475. NSF's support is gratefully acknowledged.

Please visit http://live.engin.umich.edu

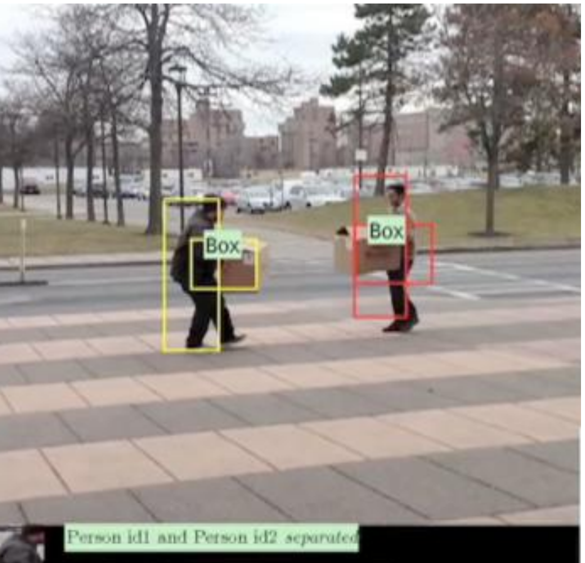
Interactive Task Learning
John Laird, CSE

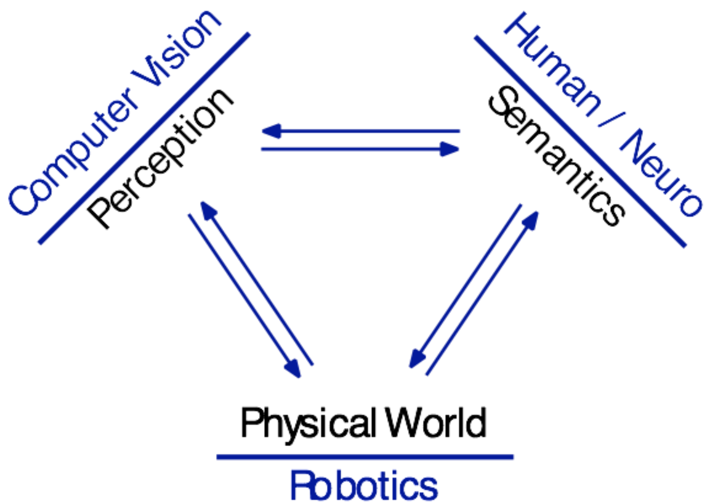
Research Goals: Create autonomous agents that learn new tasks using natural language and demonstrations; in real time during mixed initiative interaction.

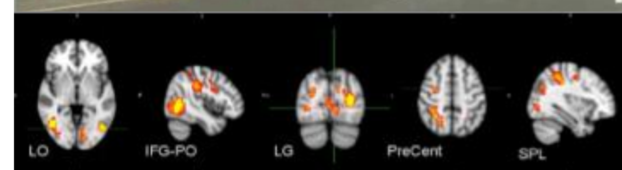
Current Progress: Learns hierarchical task specifications for block manipulation tasks, simulated kitchen activities, and fifteen games and puzzles.

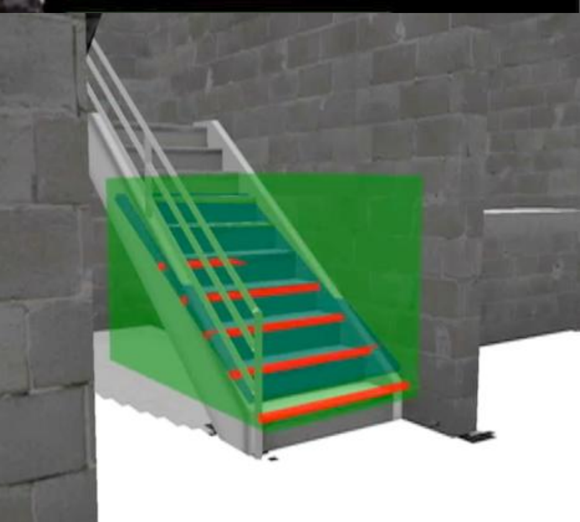
Future Plans: Extend to teaching Magic 2 mobile robot new tasks (delivery, patrol) and background behaviors (clean up).

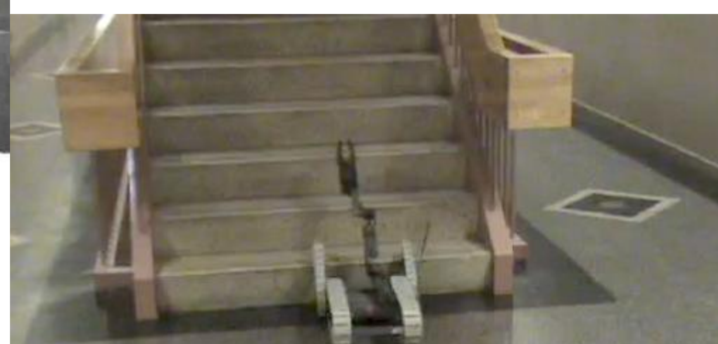
Computer Vision for Robotics
Jason Corso, ECE



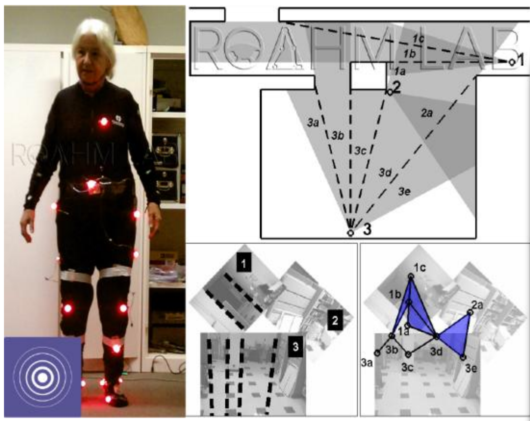








Human Interaction via Robotics and Optimization
Ram Vasudevan, ME

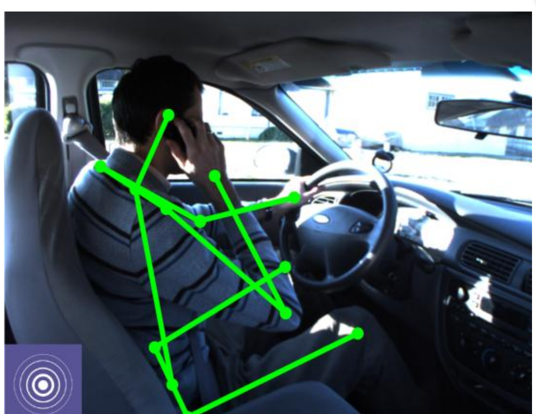


Identifying Dynamic Models

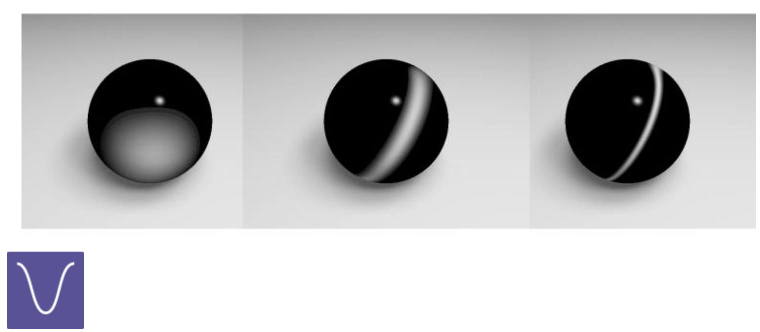
Research Goals:

- Understand and Improve Human and Robot Interaction
- Design, Control, Optimization of Semiautonomous Systems
- Personalized Diagnostics and Rehabilitation

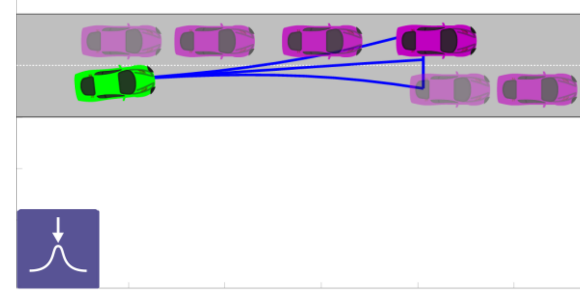
Retraining Using Virtual Reality



Identifying Models of Interaction



Predicting What People Will Do



Preventing Accidents using Automation