Hexapod Project Group

- **Project Goal is to Create a Walking Robot that can Eventually Traverse Irregular Terrain Environments Utilizing Behavioral Methods Found by Studying the Biology of Insects**

- **Professor N. Ahuja, Beckman Artificial Intelligence Group**
  Principal Investigator
- **Professor M. Nelson, Neuronal Pattern Analysis Group**
  Principal Investigator
- **Professor F. Delcomyn, Entomology Department**
  Entomology Consultant
- **John M. Hart, Research Engineer, Computer Vision and Robotics Laboratory - Project Coordinator**

  - Collaboration of Professors from Different Disciplines
  - Interaction between Students from Different Departments
  - Also, Cooperation between Different Laboratory Facilities
  - So talk is about the Research, but also People and Places...

Robot Detail

Protobot (prototype robot)

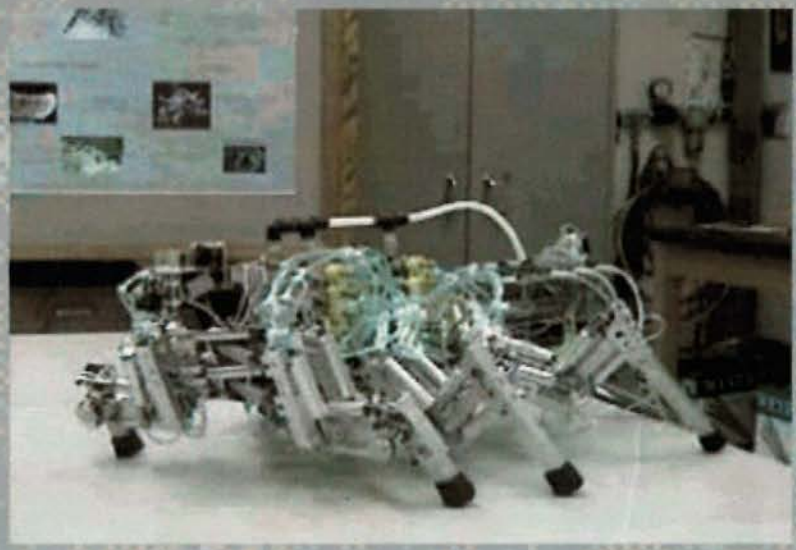
- **Two Feet Long**
- **One Foot Tall**
- **Operates using 100 psi of Compressed Air**
- **6 Legs with 3DOF**
- **18 Leg Joints**
- **36 Pneumatic Actuators**
- **36 Air Valves**
- **18 Potentiometers**
- **Tethered to PC via I/O Board and Cable**

– Robot Parts Machined by ECE Machine Shop, Chuck Henderson, Scott McDonald, Greg Cler and Billy McNeill

Insect Mechanics

- Peraplaneta Americana - the American Cockroach
- Leg Segment and Body Dimensions
- Angle of Leg Attachment

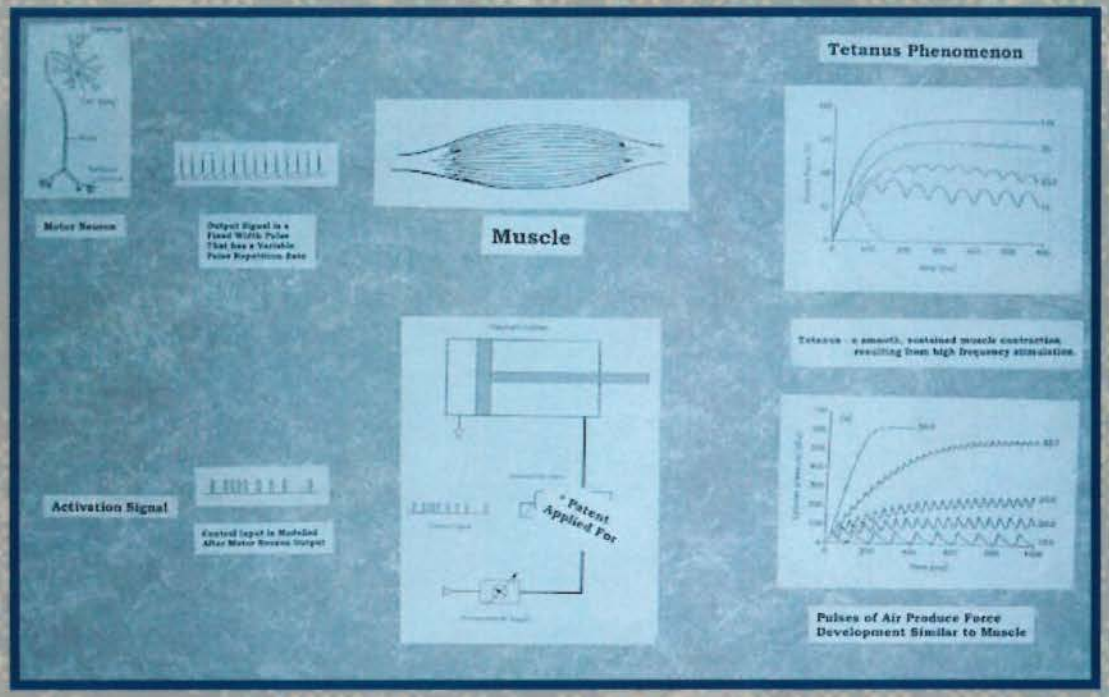
- Pneumatic Actuators Selected because of High Strength to Weight Ratio
- Proportions Propagated based on Actuator Length
- Angled Leg Planes of Insect make Body Length Much Shorter



– Insect Modeling Data Provided by Jan Cocatre-Zigien, Biology Researcher, Entomology Laboratory, Morrill Hall

– Leg Design by John M. Hart, Research Engineer, Computer Vision and Robotics Laboratory, Beckman Institute

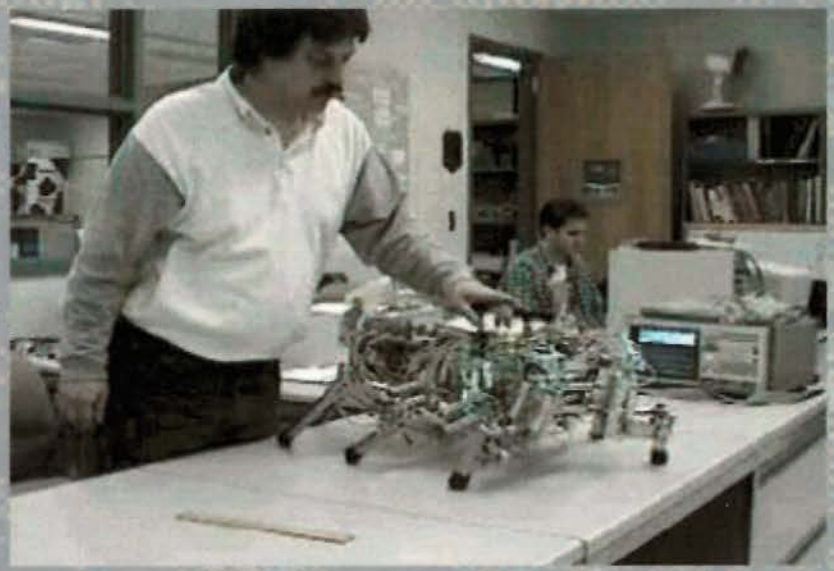
Actuator Design



- Want Actuator to Behave like Insect Muscle
- Muscle Activated by Fixed Width Action Potentials from Motor Neuron
- Train of Pulses Produces Smooth Motion

- Actuator Design by John M. Hart, Research Engineer, Computer Vision and Robotics Laboratory, Beckman Institute
- Evaluated and Improved by Jan Cocatre-Zilgien, Biology Researcher, During Testing Usually Performed on Living Muscle

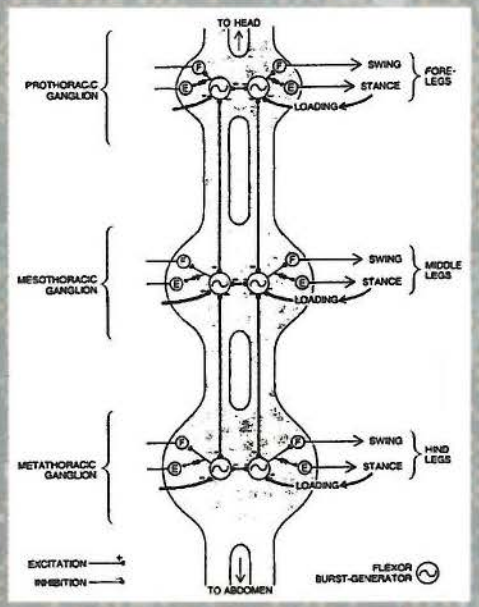
Actuator Design Cont.



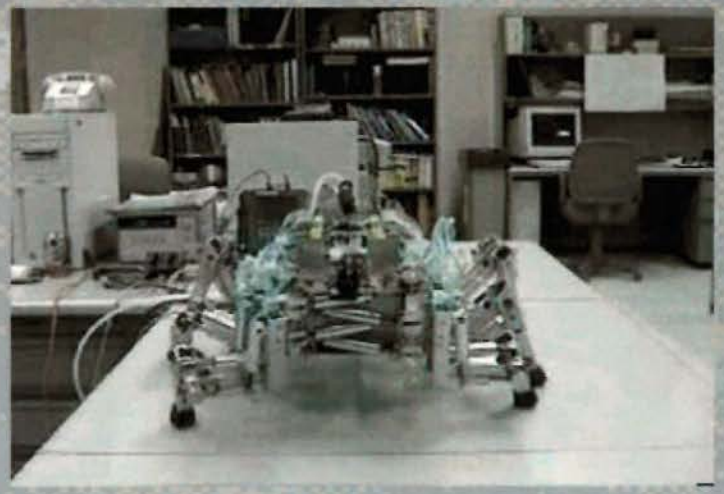
- On/Off Air Valve Signal has Fixed Width Activation Pulse
- Change Pulse Repetition Rate to Change Amount of Force Produced
- Experimentation Showed Ability to Change Compliance Similar to an Antagonistic Muscle Pair

Leg Compliance Demonstration by Larry Lu, ECE Graduate Student, Computer Vision and Robotics Laboratory, Beckman Institute

Insect Control



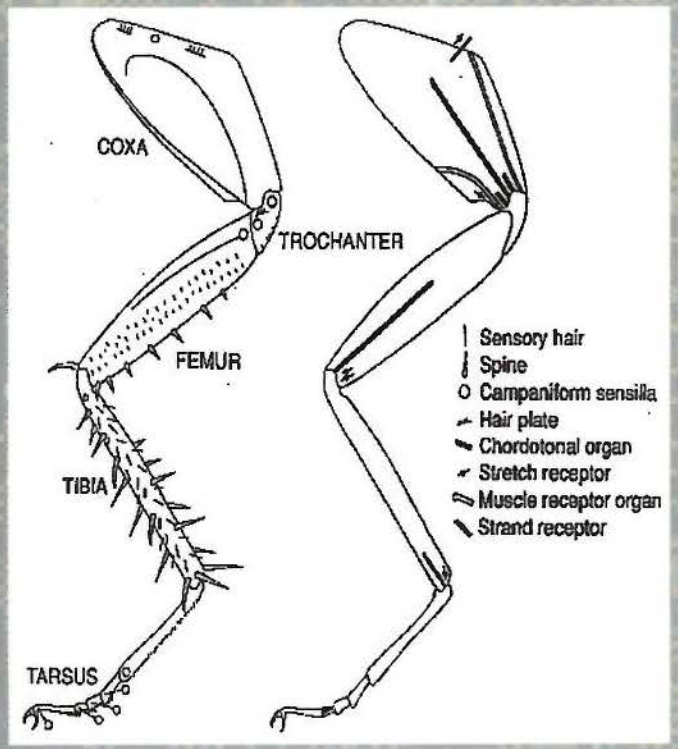
- Entomologist's Theory on Insect Nervous System Controlling Leg Motions
- We have a Single Oscillator at Each Joint
- Motion of Leg is Altered by Changing Amplitude, Midpoint, or Phase of Oscillators



- Method Used to Create Current Walking Motion over Flat Terrain
- Now Allow Sensor Inputs to Modify Oscillator Parameters

Software Design and Implementation by Kar Han Tan, ECE Graduate Student, Computer Vision & Robotics Lab, Beckman Institute

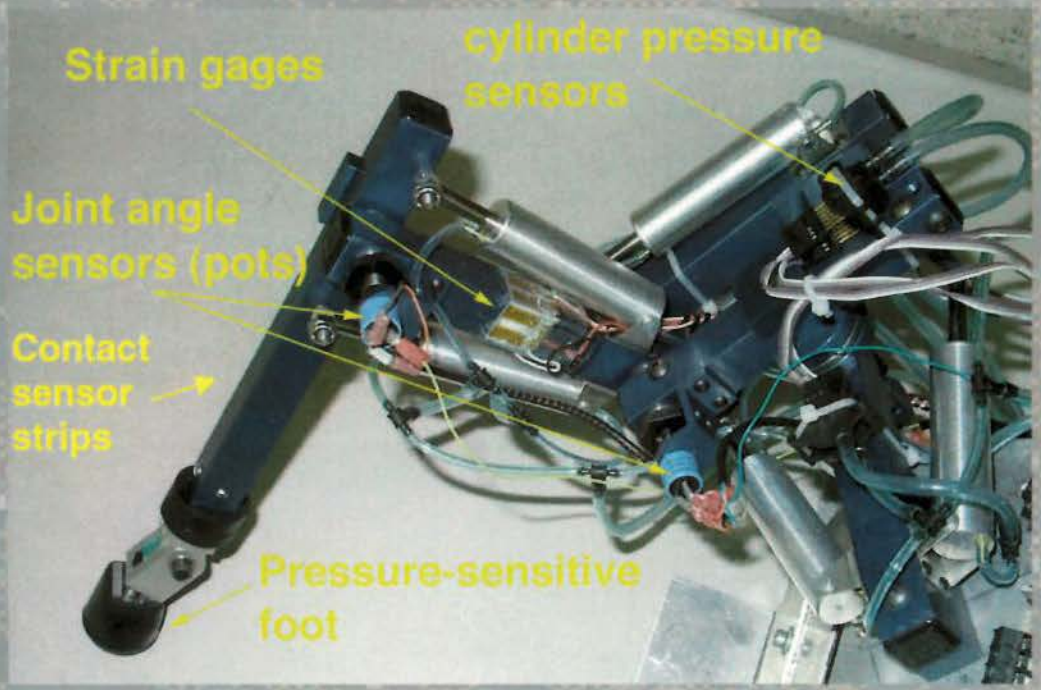
Leg Sensors



- **Three Types of Sensors Identified Contribute to the Control and Coordination of Walking in Insects**
- **Proprioceptors Indicate Positional Changes**
- **Stress Receptors Indicate Load on Leg Segments**
- **Tactile Receptors Indicate Touch Sensations**

Sensor Types Documented through Collaboration between Prof. F. Delcomyn (Entomology Dept.) and Prof. M. Nelson (Biophysics & Computational Biology)

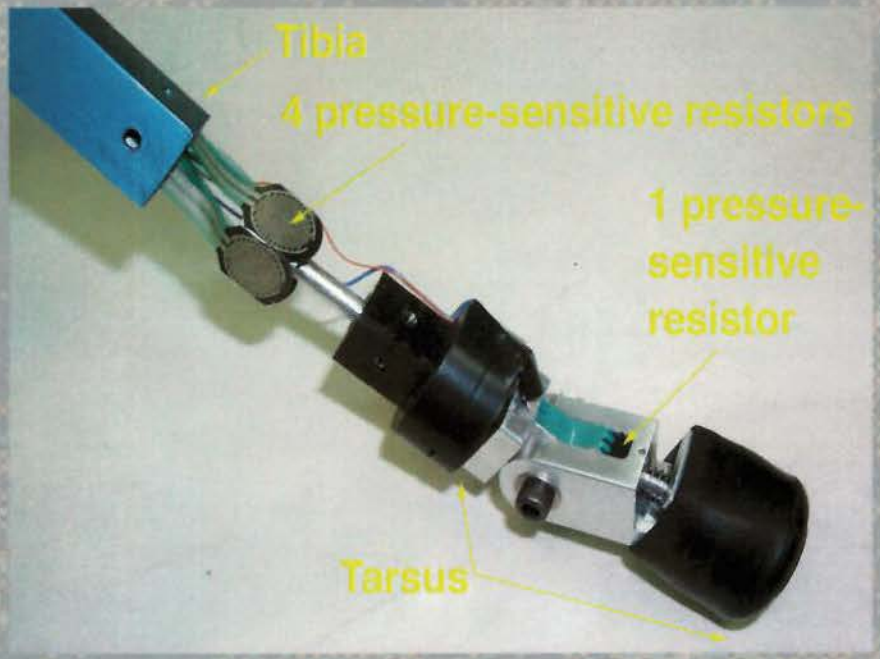
New Robot Leg



- Electromechanical Equivalents of Insect Sensors
- Potentiometers Measure Joint Angles
- Strain Gages Provide Load Information
- "Foot" Sensor Provides Ground Contact Information
- Sensor Strips Detect Obstacle Contact

- Each Sensory System Implemented by an Undergraduate Student Group from ECE's Sr. Projects Laboratory or the Advanced Digital Systems Laboratory

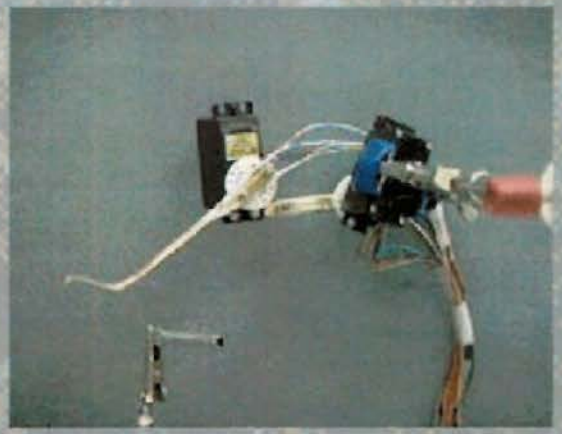
Foot Sensor



- Inspired by Insect Tarsus (or foot)
- Utilizes Pressure Sensitive Resistors
- 'Toe' Closes as Ground Contact is Made so Leg can be Slowed
- After Toe Closes, Forces are Transferred through Ball Joint to 'Ankle' Sensors
- Won Award from the ECE Department for his Design

Designed and Machined by Casey Smith, ECE Undergraduate Student, Advanced Digital Systems Laboratory, Everitt Lab

Substrate Finding Reflex



- Study of Ground Searching Motion of Actual Insects
- Neural Network Created to Implement Reflex

- Leg Sweeps Down and Encounters Substrate
- Finally Pressing Down on Substrate to Establish Foothold

Substrate Finding Reflex created by Zhimin Ding, Neuroscience PhD Student, Nelson Laboratory, Beckman Institute

Ground Searching and Restepping Reflexes programmed by Mikir Bodalia, Undergraduate Student, ECE 345 Sr. Projects Laboratory, Everitt Lab

Vision System

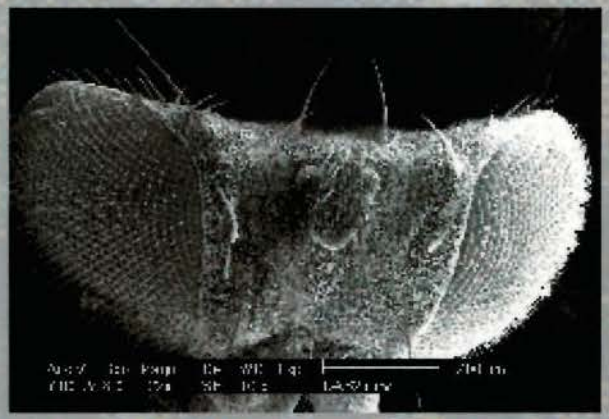
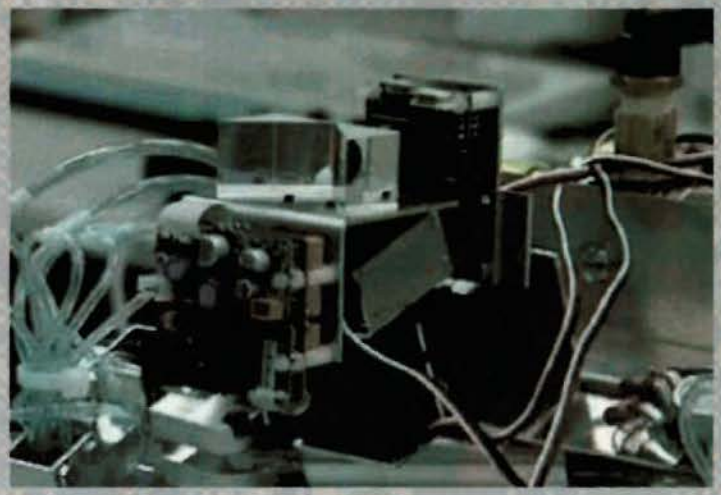


Image provided by the ITG Bugscope Project

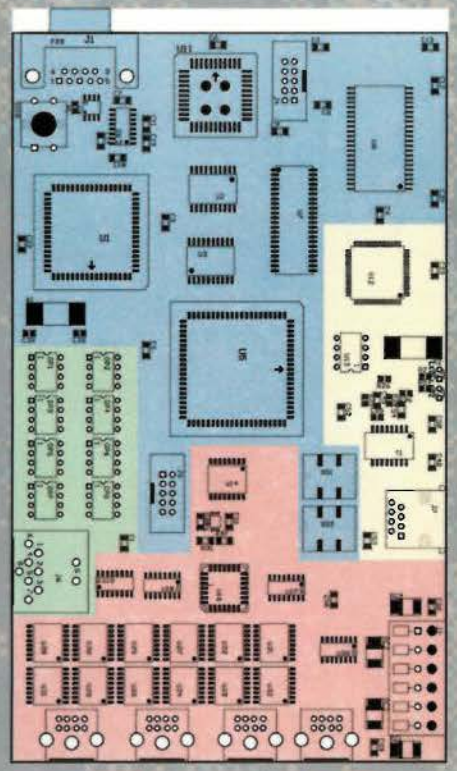
- Studying Insect Visual Systems
- Insects use Motion Cue Created by Body Movement ("ego motion")
- Can Judge Distances of Objects by Moving in a "Peering" Motion

- 3DOF CCD Camera Head
- Color Forward View
- Split Side View through Prism
- Will be used to Implement Visuomotor Behaviors



- Initial research conducted by Tony Lewis, visiting Assistant Professor, UCLA in collaboration with Prof. Ahuja (ECE) and Prof. Nelson (Biophysics & Comp. Bio.)
- Camera Head design and construction by John M. Hart, (Elect. & Comp. Eng)

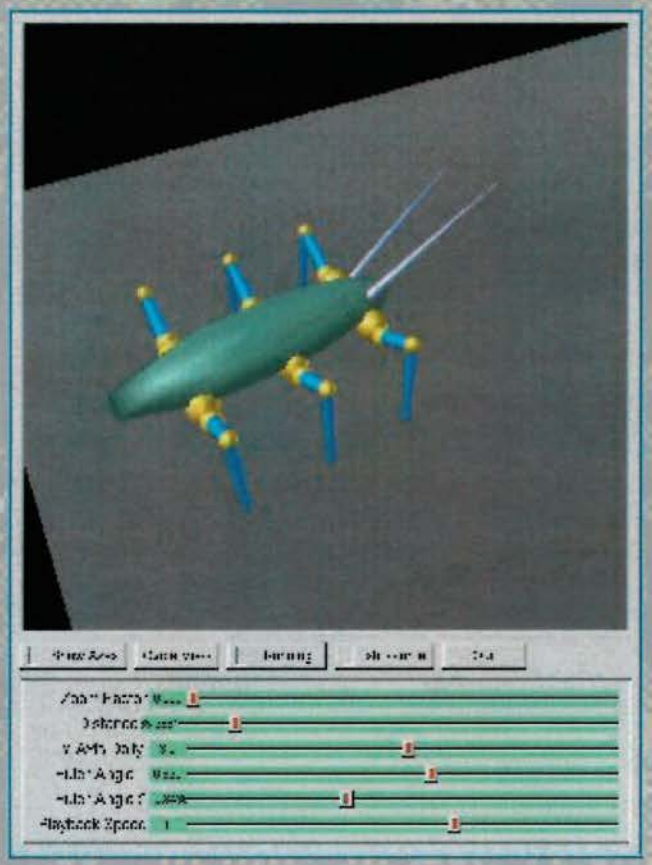
Leg Controller Board



- Future Robot "Biobot" (biological robot)
- Embedded Microcontroller Board
- One Board Controls Each Leg
- FPGA Coprocessor Samples 32 Channels of Analog Input Data and Generates 8 Channels of Digital Actuator Signals for Processor
- Ethernet Connectivity via TFTP
- Java Portal for Remote Robot Control and Data Logging Capability

- Board Design by Garrick Kremesec, Computer Engineering Undergraduate Student
- Embedded PID Control being Developed by Larry Lu, ECE Graduate Student
- Processors and Development Tools Donated by Philips through Previous Student Zhimin Ding

Simulation



- Dynamics Simulation
- Provides Resources for Physical Models of the Robot and Insect
- Simulation of Biological or Mechanical Sensors and Actuators
- Develop Animated Behaviors and Play them Back Through the Robot
- Animated Playback of Robot Mission Data

- Simulation Design and Software Coding by Jesse Reichler, CS Graduate Student, Entomology Laboratory, Morrill Hall
- Robot Actuator Modeling being done Barry Stout, ME Graduate Student

Application Areas

Current Utilization

- Platform for Entomologists to Test Their Theories of Locomotion Control
- Experimental Testbed for Visuomotor Behaviors

Future Applications

- Rough Terrain Exploration
- Hazardous Environment Surveying
- Search and Rescue
- Reconnaissance
- Demining Operations

Special Thanks

- Thanks to all the people who have contributed to our project for without their different viewpoints this project would not have been possible.

- The National Science Foundation
- The Office of Naval Research

- Prof. Ahuja's Computer Vision and Robotics Laboratory
- Prof. Nelson's Neuronal Pattern Analysis Laboratory
- Prof. Delcomyn's Entomology Laboratory

- Prof. Uribe from the Advanced Digital Systems Laboratory and also Prof. Weston and Prof. Swenson from the Sr. Projects Laboratory

- The Visualization, Imaging and Media Lab