Multi-Level Learning in Hybrid Deliberative/Reactive Mobile Robot Architectural Software Systems

Georgia Institute of Technology

DARPA MARS Kickoff Meeting - July 1999

Personnel

- Georgia Tech
  - College of Computing
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  - Georgia Tech Research Institute
    - Dr. Tom Collins
- Mobile Intelligence Inc.
  - Dr. Doug MacKenzie

Impact

- Provide the DoD community with a platform-independent robot mission specification system, with advanced learning capabilities
- Maximize utility of robotic assets in battlefield operations
- Demonstrate warfighter-oriented tools in three contexts: simulation, laboratory robots, and government-furnished platforms

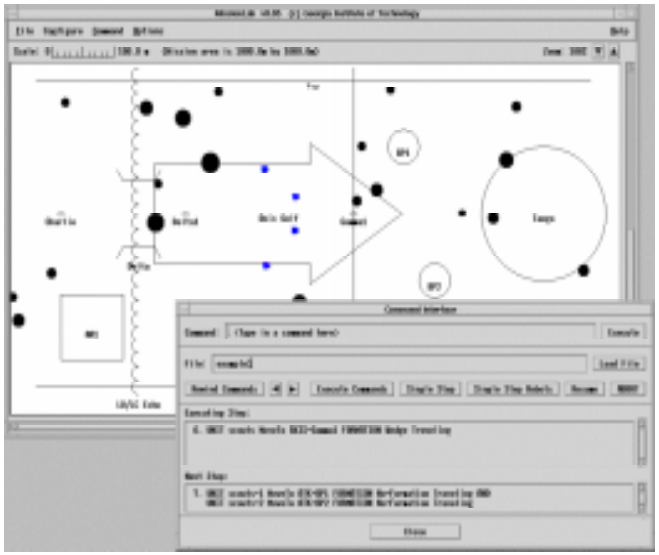
New Ideas

- Add machine learning capability to a proven robot-independent architecture with a user-accepted human interface
- Simultaneously explore five different learning approaches at appropriate levels within the same architecture
- Quantify the performance of both the robot and the human interface in military-relevant scenarios

Adaptation and Learning Methods

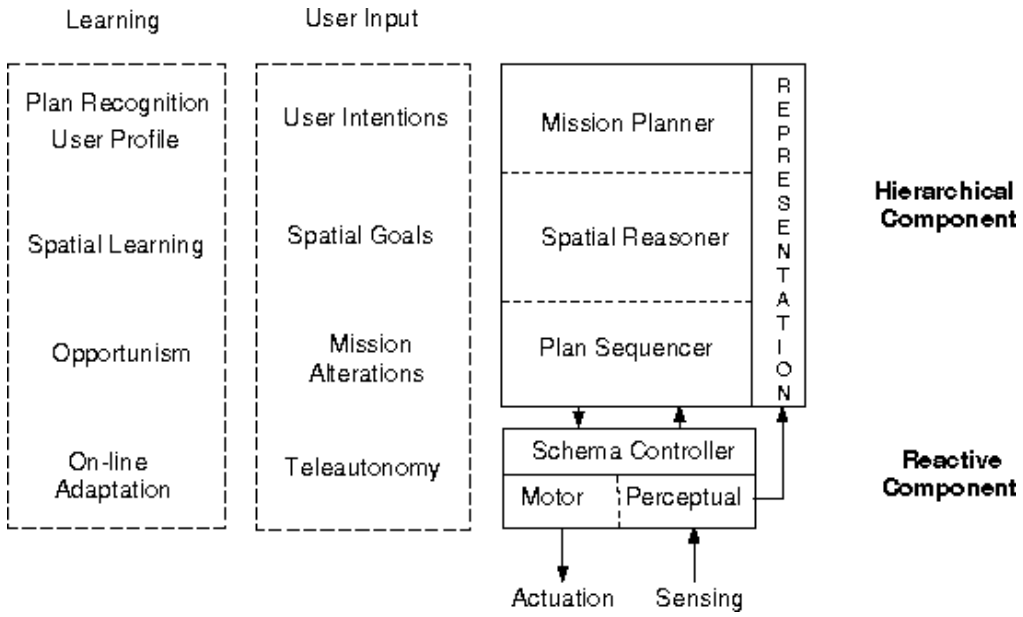
- Case-based Reasoning for:
  - deliberative guidance ("wizardry")
  - reactive situational-dependent behavioral configuration
- Reinforcement learning for:
  - run-time behavioral adjustment
  - behavioral assemblage selection
- Probabilistic behavioral transitions
  - gentler context switching
  - experience-based planning guidance

Available Robots and *MissionLab* Console



AuRA - A Hybrid Deliberative/Reactive Software Architecture

- Reactive level
  - motor schemas
  - behavioral fusion via gains
- Deliberative level
  - Plan encoded as FSA
  - Route planner available

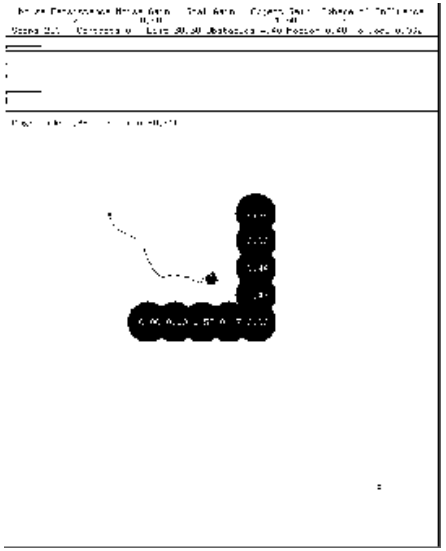


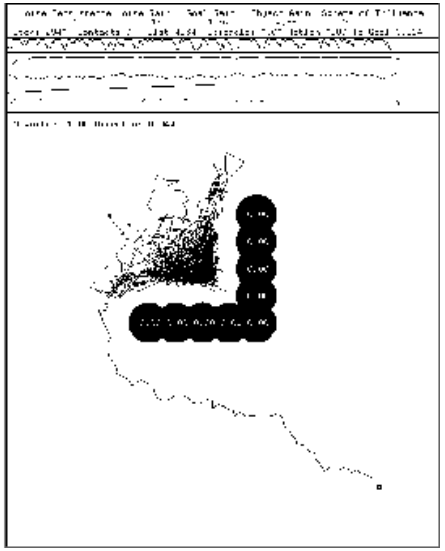
1. Learning Momentum

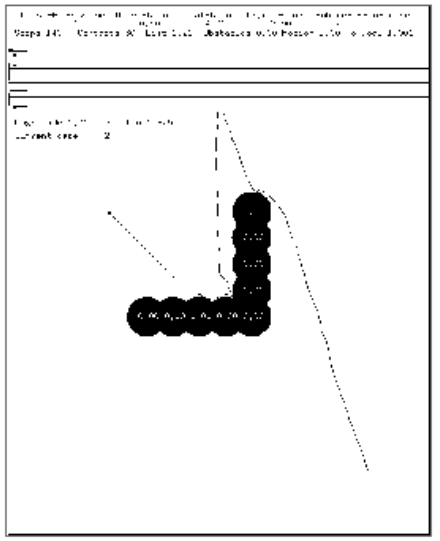
- Reactive learning via dynamic gain alteration (parametric adjustment)
- Continuous adaptation based on recent experience
- Situational analyses required
- In a nutshell: If it works, keep doing it a bit harder; if it doesn't, try something different

2. CBR for Behavioral Selection

- Another form of reactive learning
- Previous systems include: ACBARR and SINS
- Discontinuous behavioral switching

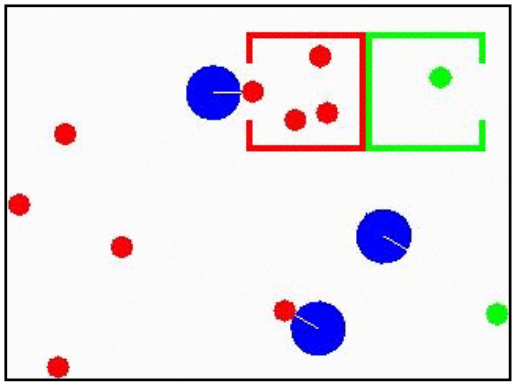


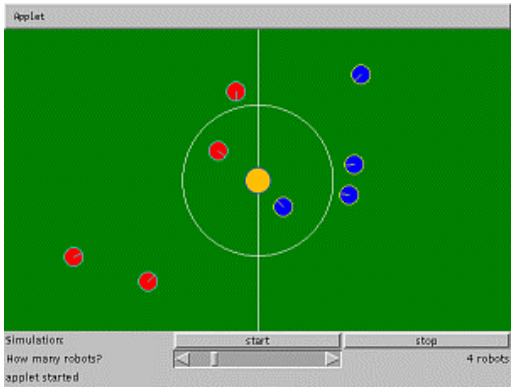




3. Q-learning for Behavioral Assemblage Selection

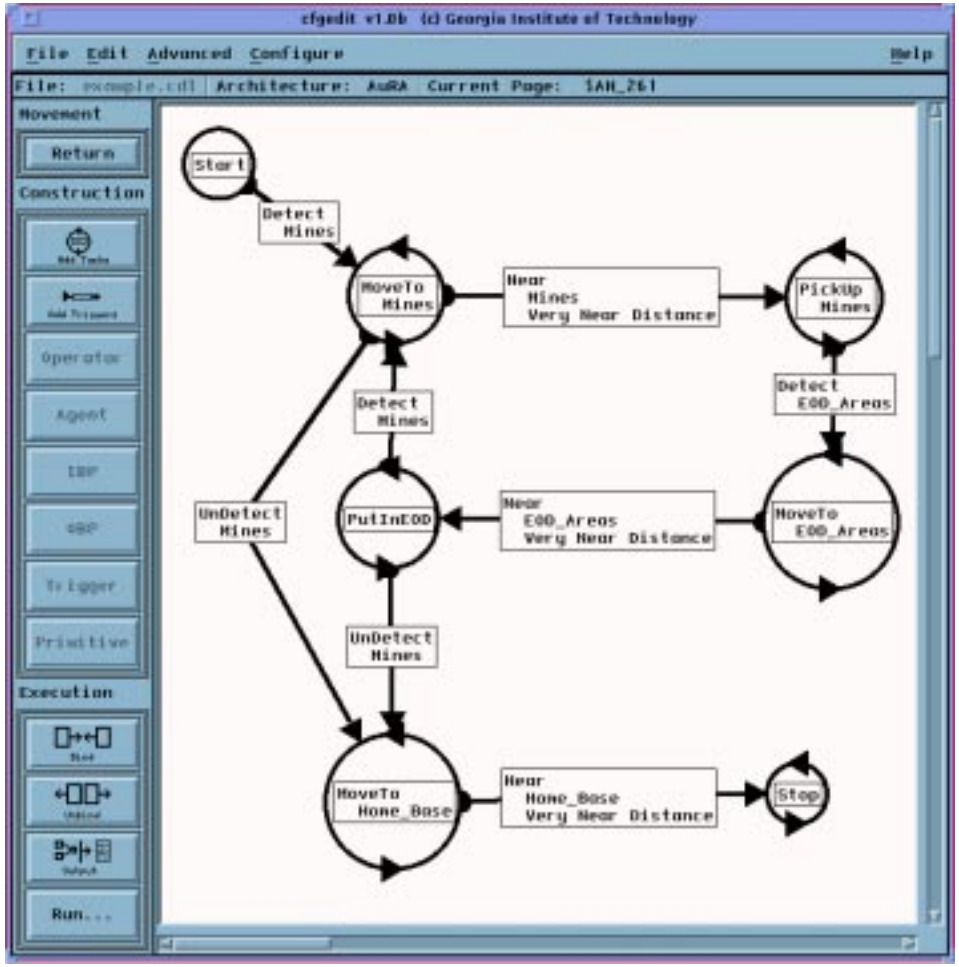
- Reinforcement learning at coarse granularity (behavioral assem-blage selection)
- State space tractable
- Operates at level above learning momentum (selection as opposed to adjustment)





4. CBR "Wizardry"

- Experience-driven assistance in mission specification
- At deliberative level above existing plan representation (FSA)
- Provides mission planning support in context



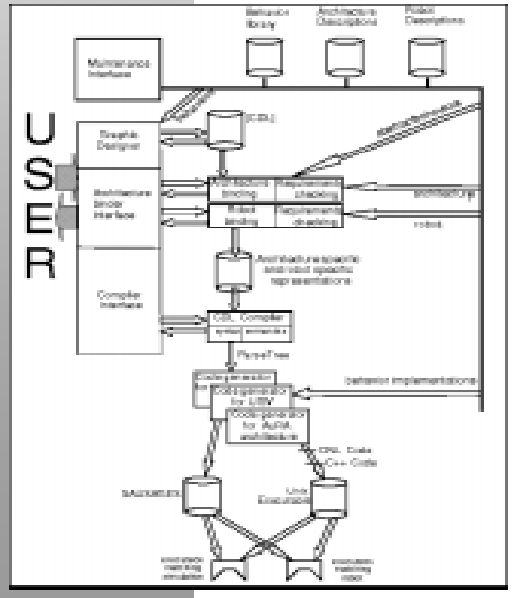
5. Probabilistic Planning and Execution

- "Softer, kinder" method for matching situations and their perceptual triggers
- Expectations generated based on situational probabilities regarding behavioral performance (e.g., obstacle densities and traversability), using them at planning stages for behavioral selection
- Markov Decision Process, Dempster-Shafer, and Bayesian methods to be investigated

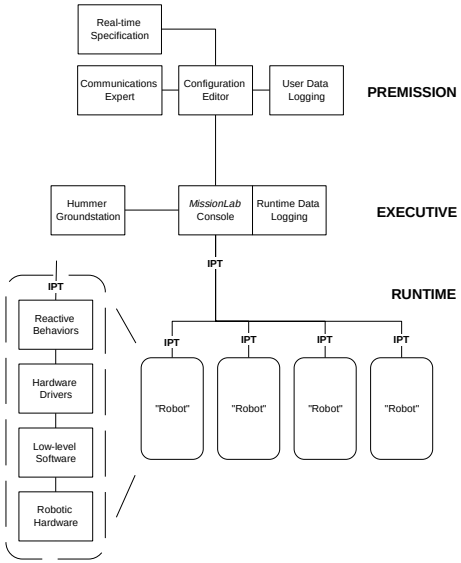
Integration with *MissionLab*

- Usability-tested Mission-specification software developed under DARPA funding (RTPC/UGV Demo II/TMR programs)
- Incorporates proven and novel machine learning capabilities
- Extends and embeds deliberative Autonomous Robot Architecture (AuRA) capabilities

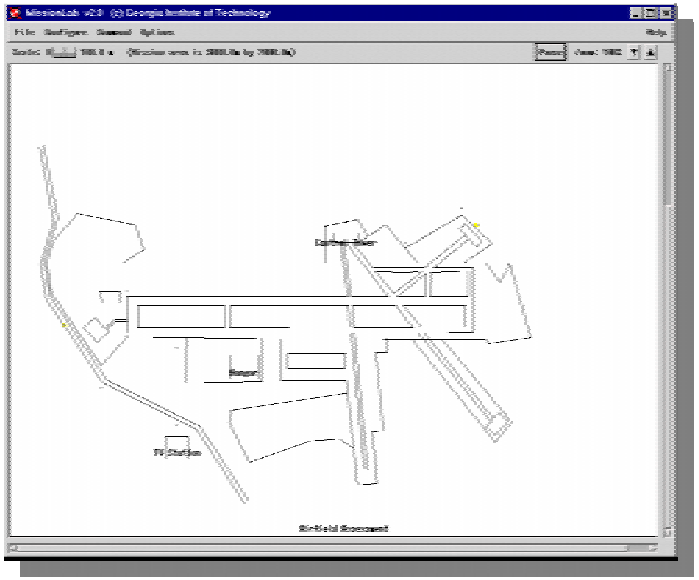
Architecture



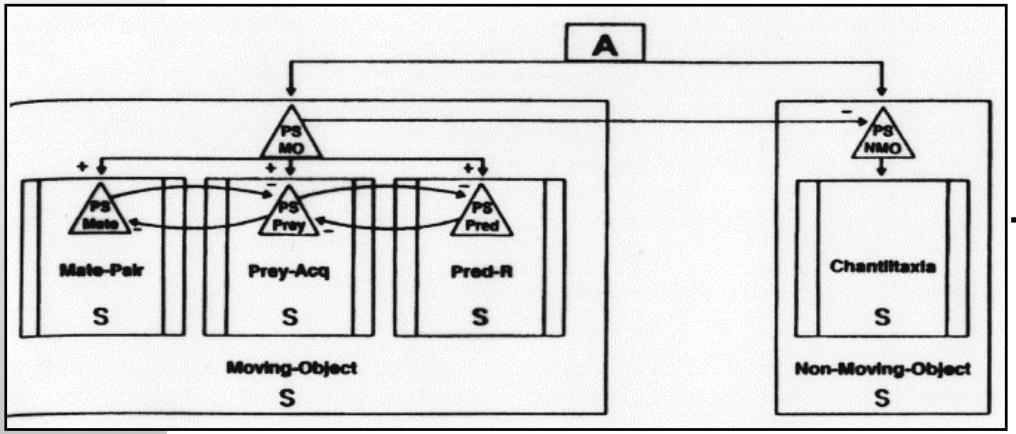
Subsystem Specification



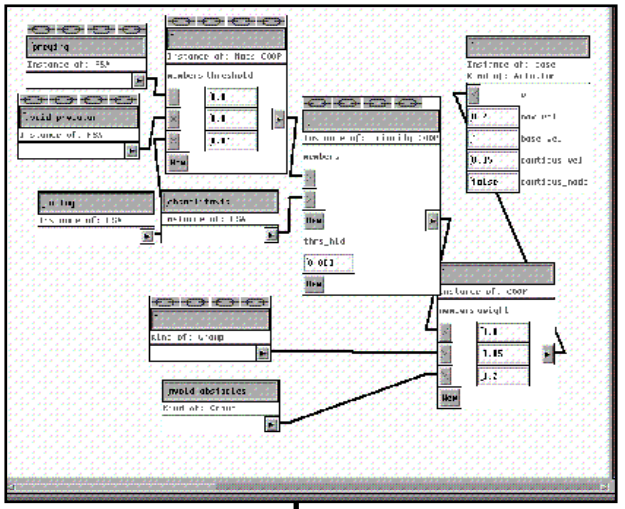
Mission Overlay



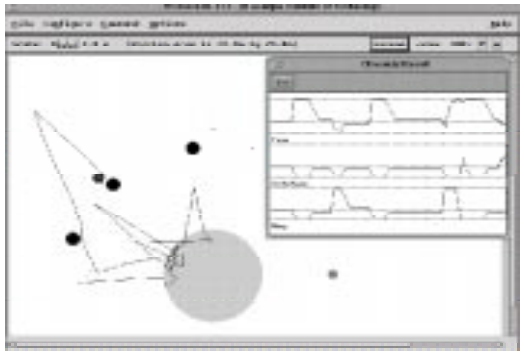
Development Process with Mlab



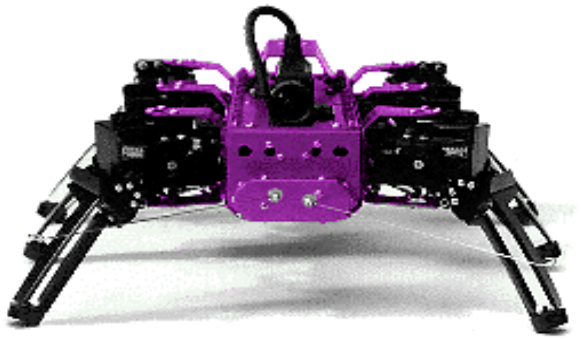
Behavioral Specification



MissionLab



Simulation

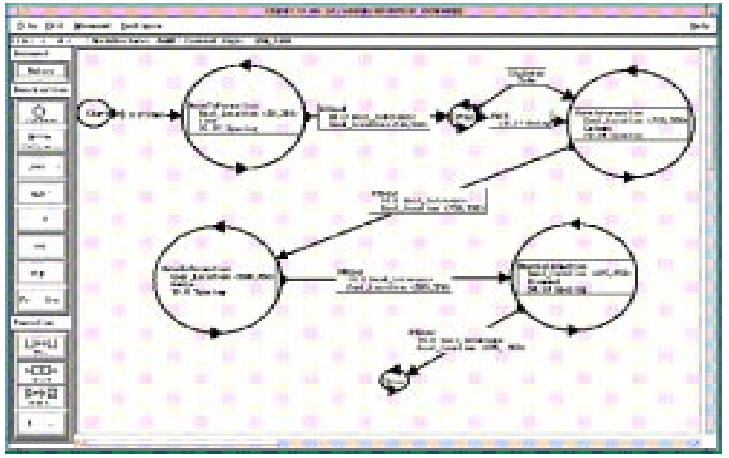


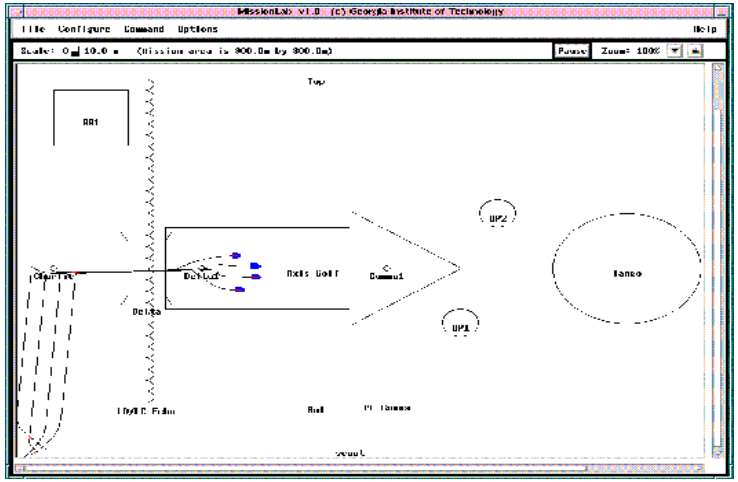
Robot

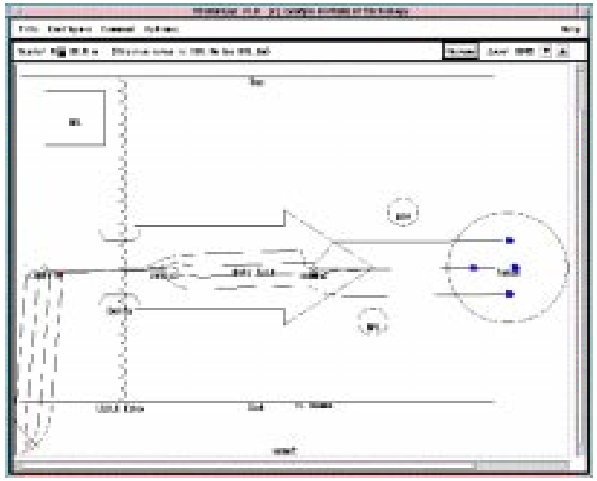
MissionLab

- Example:

  Scout Mission

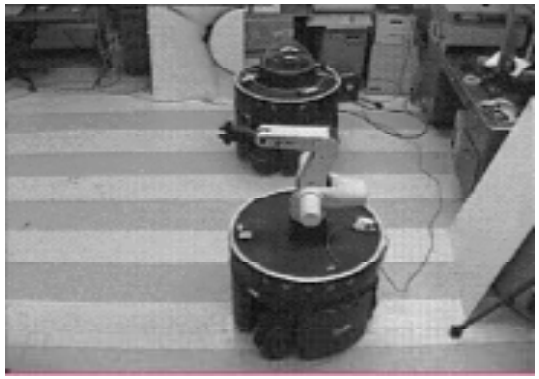


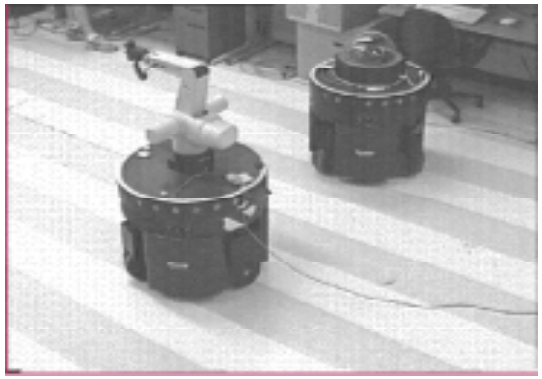


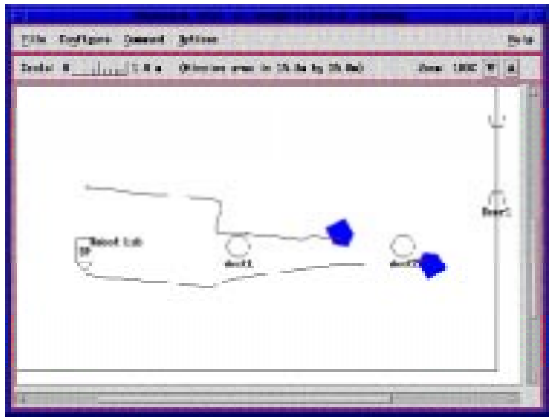


MissionLab

- **EXAMPLE: LAB FORMATIONS**

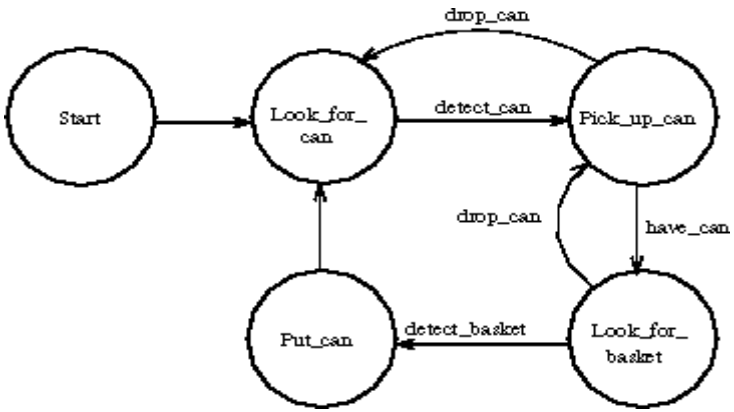


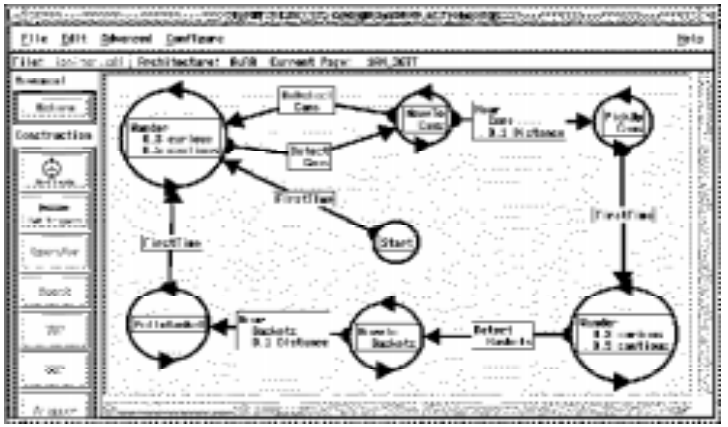


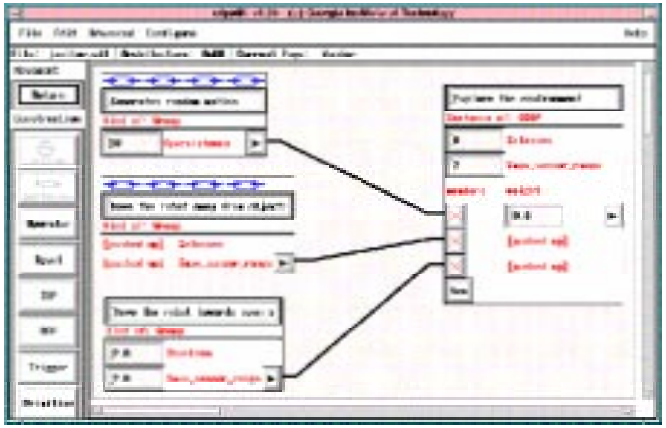


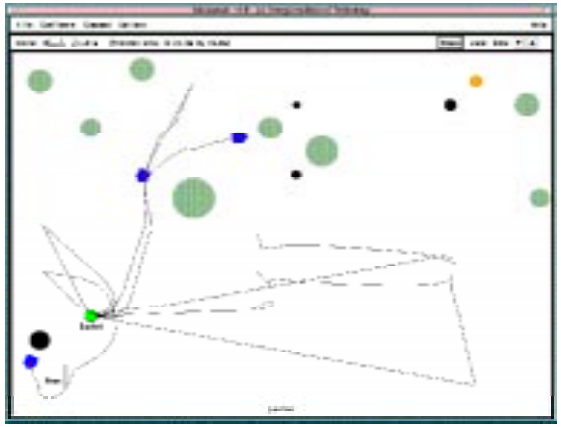
MissionLab

Example: Trashbot (AAAI Robot Competition)





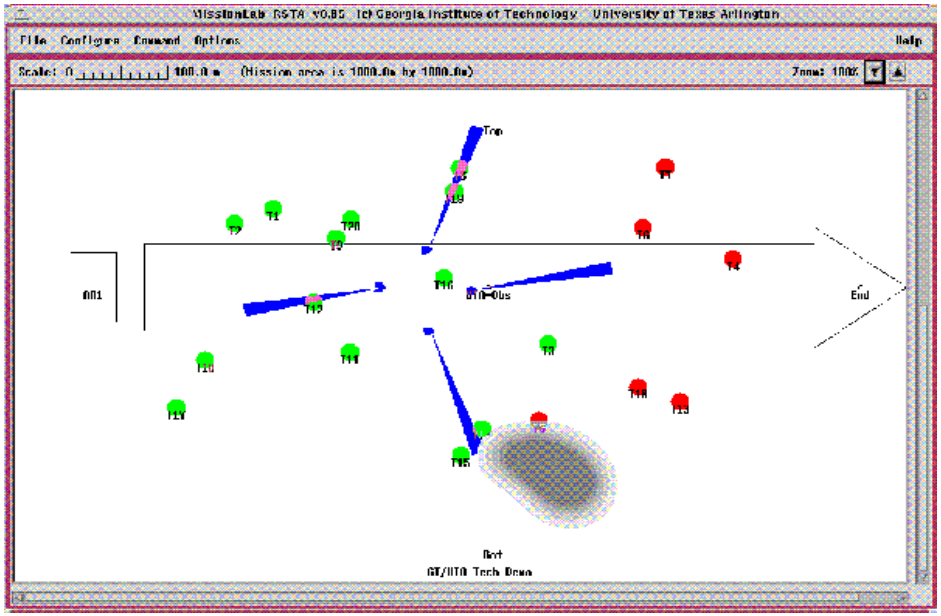




MissionLab

Reconnaissance Mission

- Developed by University of Texas at Arlington using MissionLab as part of UGV Demo II
- Coordinated sensor pointing across formations



Evaluation: Simulation Studies

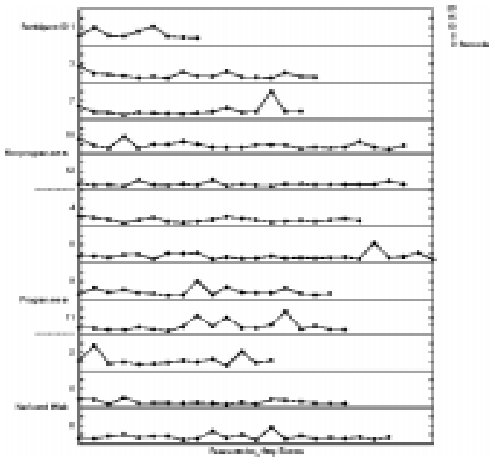
- Within *MissionLab* simulator framework
- Design and selection of relevant performance criteria for MARS missions (e.g., survivability, mission completion time, mission reliability, cost)
- Potential extension of DoD simulators, (e.g., JCATS)

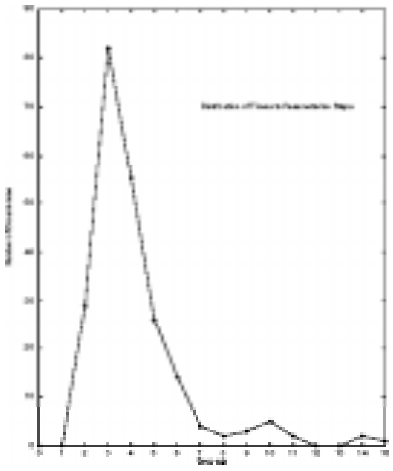
Evaluation: Experimental Testbed

- Drawn from our existing fleet of mobile robots
- Annual Demonstrations

Evaluation: Formal Usability Studies

- Test in usability lab
- Subject pool of candidate end-users
- Used for both MissionLab and team teleautonomy
- Requires development of usability criteria and metrics





Schedule

Milestone	GFY01				GFY02				GFY03				GFY04		
	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr
Demonstration of all learning algorithms in simulation			♦													
Initial integration within MissionLab on lab robots					♦											
Learning algorithms demonstrated in relevant scenarios								♦								
MissionLab demonstration on government platforms												♦				
Enhanced learning algorithms on government platforms														♦		
Final demonstrations of relevant scenarios with govt. platforms																♦